# ENGINEERING DESIGN HANDBOOK

## EXPLOSIVES SERIES

## PROPERTIES OF EXPLOSIVES OF MILITARY INTEREST

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# ENGINEERING DESIGN HANDBOOK

# PROPERTIES OF EXPLOSIVES OF MILITARY INTEREST


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# PREFACE

The Engineering Design Handbook Series of the Army Materiel Command is a coordinated series of handbooks containing basic information and fundamental data useful in the design and development of Army materiel and systems. The handbooks are authoritative reference books of practical information and quantitative facts helpful in the design and development of Army materiel so that it will meet the tactical and technical needs of the Armed Forces.

AMCP 706-177, *Properties of Explosives of Military Interest*, is one of a series on Explosives. One hundred and ten explosive compounds or mixtures are listed herein, alphabetically, with their properties, including composition variations. These explosives were selected because of their current or probable application to military use.

The tabulated data reflect the results of tests, and were first compiled for publication at Picatinny Arsenal, Dover, New Jersey, by W. R. Tomlinson, Jr. These data were later revised by Oliver E. Sheffield, also of Picatinny Arsenal, for the Engineering Handbook Office of Duke University, prime contractor to the Army Materiel Command.

The Handbooks are readily available to all elements of AMC, including personnel and contractors having a need and/or requirement. The Army Materiel Command policy is to release these Engineering Design Handbooks to other DOD activities and their contractors and to other Government agencies in accordance with current Army Regulation 70-31, dated 9 September 1966. Procedures for acquiring these Handbooks follow:

a. Activities within AMC and other DOD agencies order direct on an official form from:

Commanding Officer
Letterkenny Army Depot, ATTN: AMXLE-ATD
Chambersburg, Pennsylvania 17201

b. Contractors who have Department of Defense contracts should submit their requests through their contracting officer with proper justification to the address listed in par. a.

c. Government agencies other than DOD having need for the Handbooks may submit their requests directly to the address listed in par. a or to:

Commanding General
U. S. Army Materiel Command
ATTN: AMCAM-ABS
Washington, D. C. 20315

d. Industries not having Government contracts (this includes colleges and Universities) must forward their requests to:

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U. S. Army Materiel Command
ATTN: AMCRD-TV
Washington, D. C. 20315

e. All foreign requests must be submitted through the Washington, D. C. Embassy to:

Assistant Chief of Staff for Intelligence
Foreign Liaison Office
Department of the Army
Washington, D. C. 20310

All requests, other than those originating within DOD, must be accompanied by a *valid justification*.

Comments and suggestions on this handbook are welcomed and should be addressed to Army Research Office-Durham, Box CM, Duke Station, Durham, North Carolina 27706.

## ABBREVIATIONS AND SYMBOLS

| | |
|---|---|
| ~ | approximately. This symbol is used before numbers. |
| AC | Advisory Council on Scientific Research and Development, Great Britain. |
| ACS | American Chemical Society. |
| AISI | American Iron and Steel Institute. |
| Ann | Liebig's Annalen der Chemie. |
| Ann chim phys | Annales de chimie et de physique. |
| AP | armor-piercing. |
| APG | Aberdeen Proving Ground. |
| atm | atmosphere; atmospheric pressure. |
| Beil | Beilstein Organische Chemie, 4th Edition. |
| Ber | Berichte der Deutschen Chemischen Gesellschaft. |
| BIOS GP2-HEC | British Intelligence Overseas Service or Objective Subcommittee, Group 2, Halstead Exploiting Center. |
| BM | Bureau of Mines, United States Department of Interior. |
| Bull Soc chim | Bulletin de la societe chimique de France. |
| CA | Chemical Abstracts. |
| calc | calculated. |
| Chem Met Eng | Chemical and Metallurgical Engineering. |
| Chim et Ind | Chimie et Industrie. |
| Comp rend | Comptes rendus hebdomadaires des seances de l'Academie des Sciences (Paris). |
| cp | centipoise. |
| CR | Comptes rendus hebdomadaires des seances de l'Academie des Sciences (Paris). |
| dec | decomposes. |
| $\Delta H$ | difference in heat (i.e., heat evolved) by decomposition. |
| DRP | Deutsches Reichspatent. |
| E | modulus of elasticity or "Young's modulus"; longitudinal stress/change in length; (force/area)/(elongation/length); expressed in $lb/inch^2$. |
| E' | same as E, but expressed in $dynes/cm^2$. |
| Gazz chim ital | Gazzetta Chimica Italiana. |
| GP | general purpose. |
| HE | high explosive. |
| HEAT | high explosive antitank. |
| Ind Eng Chem | Industrial & Engineering Chemistry. |
| J Am Chem Soc | Journal of the American Chemical Society |
| J Chem Ind | The Journal of the Society of Chemical Industry (London). |
| J Chem Soc | Journal of the Chemical Society (London). |
| J Frank Inst | Journal of the Franklin Institute. |
| J Ind Explosives Soc | Journal of the Industrial Explosives Society (Japan). |
| J prakt Chem | Journal für praktische Chemie. |
| LA | lead azide |
| Land-Bornst | Landolt-Bornstein Physikalish-Chemische Tabellen, 5th Edition (Berlin). |
| M | molar. |
| M | Monatshefte für Chemie (Wein). |
| Mém poudr | Mémorial des poudres et salpêtres (Paris). |
| mg | milligram. |

ABBREVIATIONS AND SYMBOLS (cont'd)

| | |
|---|---|
| min | minimum. |
| ml | milliliter. |
| m/s | meters per second. |
| MW | molecular weight. |
| NAVORD | Bureau of Ordnance (U. S. Navy) |
| NC | nitrocellulose. |
| $n_{20}^{D}$ | index of refraction, with D band of sodium as light source, at twenty degrees centigrade. |
| NDRC | National Defense Research Committee. |
| NFOC | National Fireworks Ordnance Corporation. |
| NG | nitroglycerin. |
| NOL | U. S. Naval Ordnance Laboratory, White Oak, Silver Spring, Maryland. |
| NOTS | U. S. Naval Ordnance Test Station, China Lake, Calif. |
| NRC | National Research Council. |
| OB | oxygen balance. |
| OCM | Ordnance Committee Minutes. |
| OSRD | Office of Scientific Research and Development |
| PA | Picatinny Arsenal. |
| PATR | Picatinny Arsenal Technical Report. |
| Phil Trans | Philosophical Transactions of the Royal Society of London. |
| Pogg Ann | Poggendorf's Annalen der Physik. |
| Proc Roy Soc | Proceedings of the Royal Society of London. |
| Rec trav chim | Recueil des travaux chimiques des Pays-Bas. |
| RH | relative humidity. |
| RI | Report of Investigation. |
| SAE | Society of Automotive Engineers. |
| SAP | semi-armor-piercing. |
| sol | solution. |
| Spec | Specifications. |
| std dev | standard deviation. |
| TM | Technical Manual, Department of the Army. |
| TM/TO | joint publication, as a TM and as a Department of the Air Force Technical Order. |
| Trans Farad Soc | Transactions of the Faraday Society |
| vac stab | vacuum stability. |
| Z angew Chem | Zeitschrift für angewandte Chemie. |
| Z anorg Chem | Zeitschrift für anorganische und allgemeine Chemie. |
| Z ges Schiess-Sprengstoffw | Zeitschrift für das gesamte Schiess und Sprengstoffwessen (Munchen). |
| Z/sec | atoms of oxygen per second. |

# PROPERTIES OF EXPLOSIVES OF MILITARY INTEREST

## INTRODUCTION

1. PREDOMINANTLY A REPORT OF STANDARD TESTS. No effort was made to cover all the existing literature, either open or classified security information, on any explosive. Rather, the main resource has been reports from facilities using standard or well-known test procedures.

2. ORIGIN. Compilation of data resulting in this handbook was undertaken by Picatinny Arsenal personnel who desired to provide a manual tabulating the characteristics of explosives, based on tests, with regard to current, and possible future, interest. The first resulting Picatinny Arsenal publication was dated 20 June 1949. Revision 1, PA Technical Report No. 1740, dated April 1958, with revisions, provides the data used herein.

3. SCOPE. Tabulated data of tests on one hundred and ten explosive compounds or mixtures include sensitivity to friction, impact, heat; performance characteristics or effectiveness in weapons; physical and chemical properties; and method of preparation, synthesis or manufacture, with comments on historical origin, and supplementary references.

4. REFERENCE NOTATIONS AND SOURCES. The references, as to sources of data or for more details in methods of testing, have been listed, when available, at the end of each section devoted to a given explosive compound, explosive mixture, or explosive ingredient. Where no reference is given, it can be assumed that these data represent typical values obtained by standard procedures. When available any reference should be consulted for more details in interpreting test data.

Also there are listed Picatinny Arsenal Technical Reports which contain additional information on the particular explosive. These report numbers are given in ascending order, in columns corresponding to their terminal digits, and in accordance with the "Uniterm Index" prepared for Picatinny Arsenal by Documentation Incorporated under Contract DAI-36-034-501-ORD-(P)-42 (1955).

5. EXPLANATION OF TERMS AND METHODS OF TESTING. Data are tabulated herein on three form-type pages, in the following sequence of headings. Many of these terms are self-explanatory.

a. First tabular page.

(1) Name of the explosive in each instance.

(2) "Composition."

(3) "Impact Sensitivity, 2 Kg Wt."

(a) Impact sensitivity test for solids. (a)*

A sample (approximately 0.02 gram) of explosive is subjected to the action of a falling weight, usually 2 kilograms. A 20-milligram sample of explosive is always used in the Bureau of Mines (BM) apparatus when testing solid explosives. The weight of sample used in the Picatinny Arsenal (PA) apparatus is indicated in each case. The impact test value is the minimum

*Reference publications (a through q), applying to this introduction, are listed at the end of the introduction.

height at which at least one of 10 trials results in explosion. For the BM apparatus, the unit of height is the centimeter; for the PA apparatus, it is the inch. In the former, the explosive is held between two flat, parallel hardened (C 63 ± 2) steel surfaces; in the latter case, it is placed in the depression of a small steel die-cup, capped by a thin brass cover, in the center of which is placed a slotted-vented-cylindrical steel plug, slotted side down. In the BM apparatus, the impact impulse is transmitted to the sample by the upper flat surface, in the PA, by the vented plug. The main differences between the two tests are that the PA test (1) involves greater confinement, (2) distributes the translational impulse over a smaller area (due to the inclined sides of the die-cup cavity), and (3) involves a frictional component (against the inclined sides).

The test value obtained with the PA apparatus depends, to a marked degree, on the sample density. This value indicates the hazard to be expected on subjecting the particular sample to an impact blow, but is of value in assessing a material's inherent sensitivity only if the apparent density (charge weight) is recorded along with the impact test value. The values tabulated herein were obtained on material screened between 50 and 100 mesh, U. S. Standard Screens where single component explosives are involved, and through 50 mesh for the mixtures.

(b) Impact sensitivity test for liquids. (b)

The PA Impact Test for liquids is run in the same way as for solids. The die-cup is filled and the top of the liquid meniscus adjusted to coincide with the plane of the top rim of the die-cup. To date, this visual observation has been found adequate to assure that the liquid does not wet the die-cup rim after the brass cap has been set in place. Thus far the reproducibility of data obtained in this way indicate that variations in sample size obtained are not significant.

In the case of the BM apparatus, the procedure that was described for solids is used with the following variations:

1. The weight of explosive tested is 0.007-gm.

2. A disc of desiccated filter paper (Whatman No. 1) 9.5-millimeter diameter, is laid on each drop, on the anvil, and then the plunger is lowered on the sample absorbed in the filter paper.

(4) "Friction Pendulum Test." (c)

A 7.0-gm sample of explosive, 50-100 mesh, is exposed to the action of a steel, or fiber, shoe swinging as a pendulum at the end of a long steel rod. The behavior of the sample is described qualitatively to indicate its reaction to this experience, i.e., the most energetic reaction is explosion, and in decreasing order of severity of reaction: snaps, cracks, and unaffected.

(5) "Rifle Bullet Impact Test." (d)

Approximately 0.5-pound of explosive is loaded in the same manner as it is loaded for actual use: that is, cast, pressed, or liquid in a 3-inch pipe nipple (2-inch inside diameter, 1/16-inch wall) closed on each end by a cap. The loaded item, in the standard test, contains a small air space which can, if desired, be filled by inserting a wax plug. The loaded item is subjected to the impact of a caliber .30 bullet fired perpendicularly to the long axis of the pipe nipple, from a distance of 90 feet.

(6) "Explosion Temperature." (a)

A 0.02-gm sample (0.01-gm in the case of initiators) of explosive, loose loaded in a No. 8 blasting cap, is immersed for a short period in a Wood's metal bath. The temperature determined is that which produces explosion, ignition or decomposition of the sample in 5 seconds, and the behavior of the sample is indicated by "Explodes" or "Ignites" or "Decomposes" placed beside the value. Where values were available for times other than 5 seconds, these have been included. For 0.1-second values, no cap was used, but the explosive was placed directly on Wood's metal bath, immediately after cleaning. The value 0.1 second is estimated, not determined, and represents an interval regarded as instantaneous to the observer's eye. Dashes indicate no action.

(7) "75°C International Heat Test." (a)

A 10-gm sample is heated for 48 hours at 75°C. The sample after this exposure is observed for signs of decomposition or volatility.

(8) "100°C Heat Test." (a)

A 0.6-gm sample is heated for two 48-hour periods at 100°C. It is also noted whether exposure at 100°C for 100 hours results in explosion.

(9) "Flammability Index." (h)

The measure of the likelihood that a bare charge will catch fire when exposed to flames is the index of flammability. The test is made by bringing an oxyhydrogen flame to bear on the explosive. The maximum time of exposure which gives no ignition in 10 trials and the minimum exposure which gives ignition in each of 10 trials are determined. The index of flammability is 100 divided by the mean of the two times in seconds. The most flammable substances have high indices, e.g., 250.

(10) "Hygroscopicity."

A 5- to 10-gm sample is exposed for hygroscopicity under the stated conditions, until equilibrium is attained, or in cases where either the rate is extremely low, or very large amounts of water are picked up, for the stated time. The sample, if solid, is prepared by sieving through a 50 and on a 100 mesh screen.

(11) "Volatility."

A 10-gm sample is exposed for volatility under the stated conditions. The sample if solid is prepared by sieving through a 50 and on a 100 mesh sieve.

(12) "Molecular Weight."

The molecular weight (MW) of a mixture can be calculated from the equation

$$\text{MW of mixture} = \frac{100}{\frac{a}{mw_1} + \frac{b}{mw_2} + \frac{c}{mw_3} + \frac{n}{mw_n}}$$

where a, b, c and n are the weight percents of the components, and $mw_1$, $mw_2$, $mw_3$ and $mw_n$ their corresponding molecular weights.

(13) "Oxygen Balance."

The oxygen balance (OB) is calculated from the empirical formula of a compound in percentage of oxygen required for complete conversion of carbon to carbon dioxide (or carbon monoxide) and hydrogen to water. When metal is present the reactions are assumed to occur in the following order:

$$\text{Metal} + O \longrightarrow \text{Metal Oxide}$$

$$C + H_2O \longrightarrow CO + H_2$$

$$CO_2 + H_2 \longrightarrow CO + H_2O$$

$$2CO + O_2 \longrightarrow 2CO_2$$

Procedure for calculating oxygen balance is to determine the number of gramatoms of oxygen which are excess or deficient for 100 grams of a compound. This number multiplied by the atomic weight of oxygen gives

the oxygen balance: $1600\left(2X + \frac{Y}{2} - Z\right)$

$\div$ molecular weight of compound = oxygen balance to $CO_2$ and $H_2O$, where X = atoms of carbon, Y = atoms of hydrogen, Z = atoms of oxygen. The oxygen balance of a mixture is equal to the sum of the percent composition times the oxygen balance for each component.

The carbon/hydrogen (C/H) ratio is calculated as follows:

$$\frac{\text{Number of C atoms } (\%C + \%H)}{\text{Number of H atoms } (100)} = \text{C/H ratio}$$

(14) "Density."

(15) "Melting Point."

(16) "Freezing Point."

(17) "Boiling Point."

(18) "Refractive Index."

(19) "Vacuum Stability Test." (a)

A 5.0-gm sample (1.0 gm for initiators), after having been carefully dried, is heated for 40 hours, in vacuo at the desired temperature.

(20) "200 Gram Bomb Sand Test."

(a) Sand test for solids. (a)

A 0.4-gm sample of explosive, pressed at 3000 pounds per square inch into a No. 6 cap, is initiated by lead azide, or mercury fulminate (or, if necessary, by lead azide and tetryl), in a sand test bomb containing 200 gm of "on 30 mesh" Ottawa sand. The amount of azide, or of tetryl, that must be used, to insure that the sample crushes the maximum net weight of sand, is designated as its sensitivity to initiation and the net weight of sand crushed, finer than

30 mesh, is termed the sand test value. The net weight of sand crushed is obtained by subtracting from the total the amount crushed by the initiator when shot alone.

(b) Sand test for liquids. (b)

The sand test for liquids is made in accordance with the procedure given for solids except that the following procedure for loading the test samples is substituted:

Cut the closed end from a No. 6 blasting cap and load one end of the resulting cylinder with 0.20 gm of lead azide and 0.25 gm of tetryl, using a pressure of 3000 psi for consolidating each charge. With a pin, prick the powder train in one end of a piece of miner's black powder fuse 8 or 9 inches long. Crimp to the pricked end a loaded cylinder, taking care that the end of the fuse is held firmly against the charge in the cap. Crimp near the mouth of the cap so as to avoid squeezing the charge. Transfer a weighed portion of 0.400 gm of the test explosive to an aluminum cap, taking precautions when the explosive is liquid to insert the sample in such a manner that as little as possible adheres to the side walls of the cap, and when a solid material is being tested use material fine enough to pass through a No. 100 U. S. Standard Sieve. The caps used shall be of the following dimensions: length 2.00 inches, internal diameter 0.248-inch, wall thickness 0.025-inch. Press solid explosives, after insertion into the aluminum cap, by means of hand pressure to an apparent density of approximately 1.2 gm per cubic centimeter. This was done by exerting hand pressure on a wooden plunger until the plunger had entered the cap to a depth of 3.93 centimeters. Following are the dimensions of the interior of the cap: height 5.00 cm, area of cross section 0.312 square centimeters. Insert the cylinder containing the fuse and explosive charge of tetryl and lead azide into the aluminum cap containing the test explosive for the determination of sand crushed.

(21) "Sensitivity to Initiation."

This is sensitivity to initiation as described under the preceding heading. The minimum detonating charge, in grams, required to detonate the explosive sample, is given.

(22) "Ballistic Mortar, % TNT." (e)

The amount of sample under test which is necessary to raise the heavy ballistic mortar to the same height to which it is raised by 10 gm of trinitrotoluene (TNT) is determined. The sample is then rated, on a proportionate basis, as having a certain TNT value, i.e., as being a certain percent as effective as TNT in this respect. The formula is

$$\text{TNT value} = \frac{10}{\text{sample weight}} \times 100.$$

The ballistic mortar consists of a long compound supporting rod, at the end of which is supported a heavy short-nosed mortar. The mortar contains a chamber about 6 inches in diameter and 1 foot long. A projectile occupies about 7 inches of the chamber and the sample to be tested occupies a small portion of the remainder of the chamber. When the sample is detonated, the projectile is driven into a sand bank, and the mortar swings through an angle which is marked on paper by a pencil attached to the mortar. The angle thus indicates the height to which the pendulum is raised by the explosion, and this latter represents the energy measured by this test procedure.

(23) "Trauzl Test, % TNT." (d)

A sample of the explosive to be tested (of the order of 10 gm) is exploded in a cavity, or borehole, 25-mm in diameter and 125-mm deep, in a lead block 200-mm in diameter and 200-mm in height. The borehole is made centrally in the upper face of each block, which is cast in a mold from desilverized lead of the best quality. Although these tests have been made under a variety

of conditions, where possible the data have been taken from or related to those of Reference f (Naoum). Here a No. 8 blasting cap was used for initiation of the sample contained in glass. The weight of sample used was adjusted to give, with the initiator, a total expansion of 250 to 300 cc, since within this range expansion and sample weight were linearly related under the conditions of Naoum's test. Thus expansions for equivalent weights were readily calculated, and the test value expressed in percent of the expansion of an equivalent weight of TNT.

(24) "Plate Dent Test." (d)

Two methods were used for plate dent tests.

(a) Method A - The charge is contained in a copper tube, having an internal diameter of 3/4-inch and 1/16-inch wall. This loaded tube is placed vertically on a square piece of cold-rolled steel plate, 5/8-inch thick; 4-inch and 3-1/4-inch square plate gave the same results. The steel plate is in a horizontal position and rests in turn on a short length of heavy steel tubing 1-1/2 inches ID and 3 inches OD. The charge rests on the center of the plate, and the centers of the charge, plate, and supporting tube are in the same line. A 20-gm charge of the explosive under test is boostered by a 5-gm pellet of tetryl, in turn initiated by a No. 8 detonator.

(b) Method B - A 1-5/8-inch diameter, 5-inch long uncased charge is fired on a 1-3/4-inch thick, 5-square inch cold-rolled steel plate, with one or more similar plates as backing. The charge is initiated with a No. 8 detonator and two 1-5/8-inch diameter, 30-gm tetryl boosters.

$$\text{Plate dent test value, or relative brisance} = \frac{\text{Sample Dent Depth}}{\text{Dent Depth for TNT at 1.61 gm/cc}} \times 100.$$

(25) "Detonation Rate." (g)

The detonation rates reported in the tables contained herein were determined principally by using the rotating drum camera, under the conditions stated, e.g., usually charges 1 inch in diameter, 20 inches long, wrapped in cellulose acetate sheet, and initiated by a system designed to produce high order stable detonation at the maximum rate under the particular conditions. A typical initiating system for this consisted of four tetryl pellets 0.995 inch in diameter, 0.75 inch long, pressed to 1.50 gm/cc, with a Corps of Engineers special blasting cap placed in a central hole in the end pellet.

b. Second tabular page.

(1) "Booster Sensitivity Test." (p)

The booster sensitivity test procedure is a scaled up modification of the Bruceton method (unconfined charge). The source of the shock consists of two tetryl pellets, each 1.57 inches diameter by 1.60 inches high, of approximately 100 gm total weight. The initial shock is degraded through wax spacers of cast Acrawax B, 1-5/8 inches diameter. The test charges are 1-5/8 inches diameter by 5 inches long. The value given is the thickness of wax in inches at the 50% detonation point. The weight of tetryl pellet noted is the minimum which will produce detonation with the spacer indicated.

(2) "Heat of" (calorimetric tests). (i)

Heats of combustion and explosion are generally determined on samples weighing of the order of 1 to 2 gm, in standard calorimeter bombs such as the Parr or Emerson, approximately 400 cc (for low loading density), or the Boas, approximately 45 cc (for high loading density). For

heats of combustion the sample is burned under about 40 atmospheres of oxygen; for heats of explosion, nitrogen, or one atmosphere of air is used.

(3) "Specific Heat."

(4) "Burning Rate."

(5) "Thermal Conductivity."

(6) "Coefficient of Expansion."

(7) "Hardness, Mohs' Scale."

(8) "Young's Modulus."

(9) "Compressive Strength."

(10) "Vapor Pressure."

(11) "Decomposition Equation."

(12) "Armor Plate Impact Test." (j)

(a) 60-mm Mortar Projectile.

A modified 60-mm, M49A2, mortar projectile is loaded with the explosive to be tested, drilled to the proper depth (about 1/2 inch), and a flat-based steel plug screwed into the projectile to give a smooth close-fit between the plug base and the charge. The part of the plug outside the projectile is rounded off in the form of a spherical section. The loaded projectile with fins attached is fired from a five foot length of 2-3/8 inches ID x 3-3/8 inches OD Shelby steel tubing. The igniter and propelling charge, consisting of an igniter for a 2.36-inch rocket (bazooka), 5 gm of 4F black powder, and a quantity of shotgun propellant sufficient to give the desired velocity (read from a calibration chart) are conveniently loaded into the "gun" through a simple breech plug. The velocities are measured electronically, and the reaction, inert or affected, is determined by observation (e.g., whether or not flash occurs on impact). Within the range of flight stability of the projectile, 200-1100 ft/sec, the 50% point is located.

(b) 500-lb General Purpose Bombs.

(13) "Bomb Drop Test."

Bomb drops are made using bombs assembled in the conventional manner, as for service usage, but containing either inert or simulated fuzes. The target is usually reinforced concrete.

c. Third tabular page.

(1) "Fragmentation Test." (1)

The weight of each empty projectile and weight of water displaced by the explosive charge is determined, and from this the specific gravity of the charge is calculated. All 3-inch and 90-mm projectiles are initiated by M20 Booster pellets, and those used with 3-inch HE, M42A1, Lot KC-5 and 90-mm HE, M71, Lot WC-91 projectiles are controlled in weight and height as follows: 22.50 $\pm$ 0.10 gm, and 0.480 to 0.485 inch.

The projectile assembled with fuze, actuated by a Blasting Cap, Special, Type II (Spec 49-20) placed directly on a lead of comparable diameter, and booster, are placed in boxes constructed of half-inch pine. The 90-mm projectiles are fragmented in boxes 21 x 10-1/2 x 10-1/2 inches and the 3-inch projectiles in boxes 15 x 9 x 9 inches outside dimensions. The box with projectile is placed on about 4 feet of sand in a steel fragmentation tub, the detonator wires are connected, and the box covered with approximately 4 feet more of sand. The projectile is fired and the sand run onto a gyrating 4-mesh screen on which the fragments are recovered.

(2) "Fragment Velocity."

Charges 10-1/8 inches long and 2 inches in diameter, containing a booster cavity, filled by a 72-gm tetryl pellet (1-3/8 inches diameter, 2 inches long, average density 1.594) are fired in a model projectile of Shelby seamless tubing, 2 inches ID, 3 inches OD, SAE 1020 steel, with a welded-on cold rolled steel base. The projectile is so fired in a chamber, connected to a corridor containing velocity stations, that a desired wedge of projectile casing fragments can be observed. The fragment velocities are determined by shadow photographs, using flash bulbs, and rotating drum cameras, each behind three slits. The drum cameras have a writing speed of 30 meters per second.

(3) "Blast (Relative to TNT)."

The blast pressures and impulses given were determined almost exclusively with tourmaline gages, and the usual necessary specialized electrical circuits, shielded co-axial cables, oscillographs, etc. In general, the data represent results of tests with large cased charges.

(4) "Shaped Charge Effectiveness, TNT = 100." (k, m)

Unconfined charges 2 inches in diameter and 6 inches long, boostered by a 10-gm pressed tetryl pellet, set in a 20-mm pellet (truncated cone) of cast 60/40 cyclotol, are shot against 3-inch homogeneous armor plate at a 1-3/16 inches standoff. The cones used are commercial Pyrex glass funnels, sealed off at the start of the stem, 2 inches in diameter, 0.110 to 0.125 inch wall thickness.

Unconfined charges 1.63 inches in diameter and 6 inches long are tested at a standoff of 1.63 inches against stacks of 4 x 4 x 1 inch mild steel plates. M9A1 steel cones are used. Results are averages of 4 trials.

(5) "Color."

(6) "Principal Uses."

(7) "Method of Loading."

(8) "Loading Density."

(9) "Storage."

Ammunition and bulk explosives in storage represent varying degrees of hazard and compatibility. This has led to their being divided into a number of hazard classes and compatibility groups as indicated in subparagraphs (b) and (c) below.

(a) Method: Wet or dry.

(b) Hazard Class (Quantity-Distance).

Ammunition and bulk explosives are divided into quantity-distance classes, Class 1 through 12, according to the damage expected if they explode or ignite (Reference: Army Materiel Command Regulation, AMCR 385-100, AMC Safety Manual, chapter 17). All standard explosives in bulk are included in four of these classes: Class 2, 2A, 9, and 12 (TM 9-1910/TO 11A-1-34).

(c) Compatibility Group.

Explosives and ammunition are grouped for compatibility with respect to the following factors:

1. Effects of explosion of the item.

2. Rate of deterioration.

3. Sensitivity to initiation.

4. Type of packing.

5. Effects of fire involving the item.

6. Quantity of explosive per unit.

(d) Exudation.

d. Miscellaneous entries.

Where available and appropriate, the following or related data are given, in space at the bottom of the third form, or on plain pages.

(1) Solubility.

(2) Methods of manufacture.

(3) Historical information.

(4) Bulk compressibility modulus. (q)

The direct experimental measurement of the dynamic bulk modulus of a solid is difficult, and few such measurements have been made. One apparatus has been developed at the Naval Ordnance Laboratory and is described in detail in Reference q. Bulk modulus (its reciprocal is the compressibility) is defined as the ratio of stress to strain when the stress is a pressure applied equally on all surfaces of the sample and the strain is the resulting change in volume per unit volume.

(5) Hydrolysis tests. (o)

The 240-hour hydrolysis test is conducted as follows: A 5-gm sample of the dry nitrocellulose is weighed accurately in a tare-weighed 250-cc Pyrex flask having a ground glass connection for a Pyrex condenser. Then 100 cc of distilled water is added to the nitrocellulose in the flask and the flask fitted to the condenser. The flask is placed in a steam bath in which the water is kept boiling constantly by means of electric hotplates. At the end of 240 hours the amount of solid developed by the hydrolysis of the nitrocellulose is measured by an electromatic pH method.

(6) Sensitivity to initiation by electrostatic discharge. (n)

The samples are tested under two amounts of confinement, designated as unconfined and confined. In the unconfined test, a sample of approximately 0.05 gm is dumped into a shallow depression in a steel block and flattened out with a spatula. In the confined tests (partly confined), the sample of approximately 0.05 gm is introduced into soft-glass tube (~ 7 mm ID x 18 mm long) which fits over a metal peg. The volume of the space around the charge at zero gap is ~ 0.15 cc; at a gap of 0.6 mm, it is ~ 0.4 cc. In addition to providing moderate confinement, this system also minimizes dispersion of the sample by the test spark, and reduces the effect of material being repelled from the needle point by electrostatic field effect.

When a test is to be made, the needle point electrode is screwed up until the gap between electrodes is greater than the critical gap discharge at the test voltage. The sample is then placed in position, the high-voltage terminal of the charged condensor is switched to the point electrode by means of a mercury switch, and the electrode is screwed down until discharge occurs.

The spark energy (in joules), for zero probability of ignition, is determined.

(7) Destruction by chemical decomposition.

Burning is the preferred method of destroying explosives. Initiating type explosives (in quantity) are usually destroyed by detonation with demolition blocks. Destruction of explosives by chemical decomposition can be effectively used where small laboratory quantities are involved. Procedures given are standard for only lead azide, mercury fulminate and nitroglycerin.

(8) Other information.

(9) References.

## 6. REFERENCES CITED IN INTRODUCTION.[1]

a. W. H. Rinkenbach and A. J. Clear, Standard Laboratory Procedures for Sensitivity, Brisance, and Stability of Explosives, PATR No. 1401, 18 March 1944, Revised 28 February 1950.

b. W. R. Tomlinson, Jr. and A. J. Clear, Development of Standard Tests -- Application of the Impact and Sand Tests to the Study of Nitroglycerin and Other Liquid Explosives, PATR No. 1738, 13 June 1949.

c. J. H. McIvor, Friction Pendulum, PA Testing Manual 7-1, 8 May 1950.

d. Departments of the Army and the Air Force Joint Technical Manual and Technical Order, TM 9-1910/TO 11A-1-34, Military Explosives, April 1955.

e. J. H. McIvor, Ballistic Mortar Test, PA Testing Manual 7-2, 8 May 1950.

f. Ph. Naoum, Z ges Schiess-Sprengetoffw, pp. 181, 229, 267 (27 June 1932).

g. G. J. Mueller, Equipment for the Study of the Detonation Process, PATR No. 1465, 4 July 1945.

h. NDRC Interim Report, Preparation and Testing of Explosives, Nos. PT-19 and PT-20, February-April 1944.

i. Linnie E. Newman, PA Chemical Laboratory Report Nos. 127815 and 134476, 11 January 1951.

j. Report AC-2983/Org Expl 179.

[1]For information regarding source of references, inquiries should be made to the Commander, U.S. Army Research Office--Durham, ATTN: CRDARD-EH, Box CM, Duke Station, Durham, North Carolina 27706.

k. Eastern Laboratory, du Pont, Investigation of Cavity Effect, Section III, Variation of Cavity Effect with Composition, NDRC Contract W-672-ORD-5723.

l. J. H. McIvor, Fragmentation Test Procedures, PA Testing Manual 5-1, 24 August 1950.

m. Eastern Laboratory, du Pont, Investigation of Cavity Effect, Final Report, 18 September 1943, NDRC Contract W-672-ORD-5723.

n. F. W. Brown, D. H. Kusler, and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Department of Interior, Bureau of Mines, R. I. 3852, 1946.

o. D. D. Sager, Study of Acid Adsorption and Hydrolysis of Cellulose Nitrate and Cellulose Sulphate, PATR No. 174, 12 January 1932.

p. L. C. Smith and E. H. Eyster, Physical Testing of Explosives, Part III, Miscellaneous Sensitivity Tests, Performance Tests, OSRD Report No. 5746, 27 December 1945.

q. C. S. Sandler, An Acoustic Technique for Measuring the Effective Dynamic Bulk Modulus of Elasticity and Associated Loss Factor of Rubber and Plastics, NAVORD Report No. 1524, 1 September 1950.

W. S. Cramer, Bulk Compressibility Data on Several Explosives, NAVORD Report No. 4380, 15 September 1956.

Amatol, 80/20

**Composition:**
%

| | |
|---|---|
| Ammonium Nitrate | 80 |
| TNT | 20 |

C/H Ratio

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 90 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 15 |
| Sample Wt, mg | 17 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | Unaffected |

**Rifle Bullet Impact Test:** 5 Trials

| | % |
|---|---|
| Explosions | 0 |
| Partials | 0 |
| Burned | 0 |
| Unaffected | 100 |

**Explosion Temperature:** °C

Seconds, 0.1 (no cap used)

| | |
|---|---|
| 1 | |
| 5 | Decomposes 280 |
| 10 | |
| 15 | |
| 20 | |

**75°C International Heat Test:**

| | |
|---|---|
| % Loss in 48 Hrs | 0.06 |

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.03 |
| % Loss, 2nd 48 Hrs | 0.05 |
| Explosion in 100 Hrs | None |

**Flammability Index:**

**Hygroscopicity:** %

| | |
|---|---|
| 30°C, 90% RH, 2 days | 61 |

**Volatility:** Nil

**Molecular Weight:** 92

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | +1 |
| CO % | +11 |

**Density:** gm/cc Cast 1.46

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$

$n_{25}^{D}$

$n_{30}^{D}$

**Vacuum Stability Test:**

cc/40 Hrs, at

| | |
|---|---|
| 90°C | |
| 100°C | 0.45 |
| 120°C | 0.95 |
| 135°C | |
| 150°C | 6.8 |

**200 Gram Bomb Sand Test:**

| | |
|---|---|
| Sand, gm | 35.5 |

**Sensitivity to Initiation:**

Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | |
| Lead Azide | 0.20 |
| Tetryl | 0.07 |

**Ballistic Mortar, % TNT:** (a) 130

**Trauzl Test, % TNT:** (b) 123

**Plate Dent Test:**

| | |
|---|---|
| Method | |
| Condition | |
| Confined | |
| Density, gm/cc | |
| Brisance, % TNT | |

**Detonation Rate:**

| | | |
|---|---|---|
| Confinement | None | None |
| Condition | Cast | Cast |
| Charge Diameter, in. | 1.0 | 1.0 |
| Density, gm/cc | 1.46 | 1.50 |
| Rate, meters/second | 4500 | 5100 |

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec (f)
At 9 ft 1900
At 25½ ft 1750
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Buff-yellow

**Principal Uses:** Bombs, HE projectiles

**Method of Loading:** Cast

**Loading Density:** gm/cc 1.46

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | Does not exude at 65°C |

Booster Sensitivity Test: (a)

| | |
|---|---|
| Condition | Pressed |
| Tetryl, gm | 100 |
| Wax, in. for 50% Detonation | 0.83 |
| Density, gm/cc | 1.65 |

Heat of: (d, e)

| | |
|---|---|
| Combustion, cal/gm | 1002* |
| Explosion, cal/gm | 490* |
| Gas Volume, cc/gm | 930* |

*Calculated from composition of mixture.

Amatol, 60/40

**Composition:**
%

| | |
|---|---|
| Ammonium Nitrate | 60 |
| TNT | 40 |

C/H Ratio

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 95 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 16 |
| Sample Wt, mg | 17 |

**Friction Pendulum Test:**
Steel Shoe
Fiber Shoe

**Rifle Bullet Impact Test:** Trials

%

Explosions
Partials
Burned
Unaffected

**Explosion Temperature:** °C

Seconds, 0.1 (no cap used)

1
5 Decomposes 270
10
15
20

**75°C International Heat Test:**
% Loss in 48 Hrs

**100°C Heat Test:**
% Loss, 1st 48 Hrs
% Loss, 2nd 48 Hrs
Explosion in 100 Hrs

**Flammability Index:**

**Hygroscopicity:** %

**Volatility:** Nil

**Molecular Weight:** 108

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -18 |
| CO % | + 2 |

**Density:** gm/cc Cast 1.60

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$
$n_{25}^{D}$
$n_{30}^{D}$

**Vacuum Stability Test:**
cc/40 Hrs, at
90°C
100°C
120°C
135°C
150°C

**200 Gram Bomb Sand Test:**
Sand, gm 41.5

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | |
| Lead Azide | 0.20 |
| Tetryl | 0.06 |

**Ballistic Mortar, % TNT:** (a) 128

**Trauzl Test, % TNT:**

**Plate Dent Test:**
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**Detonation Rate:**

| | |
|---|---|
| Confinement | None |
| Condition | Cast |
| Charge Diameter, in. | 1.0 |
| Density, gm/cc | 1.50 |
| Rate, meters/second | 5760 |

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

| | |
|---|---|
| Density, gm/cc | 1.49 |
| Charge Wt, lb | 1.971 |
| **Total No. of Fragments:** | |
| For TNT | 703 |
| For Subject HE | 583 |

**3 inch HE, M42A1 Projectile, Lot KC-5:**

| | |
|---|---|
| Density, gm/cc | 1.57 |
| Charge Wt, lb | 0.827 |
| **Total No. of Fragments:** | |
| For TNT | 514 |
| For Subject HE | 408 |

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

| | |
|---|---|
| **Air:** | |
| Peak Pressure | 95 |
| Impulse | 85 |
| Energy | 84 |
| **Air, Confined:** | |
| Impulse | |
| **Under Water:** | |
| Peak Pressure | |
| Impulse | |
| Energy | |
| **Underground:** | |
| Peak Pressure | |
| Impulse | |
| Energy | |

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Buff-yellow

**Principal Uses:** Bombs, HE projectiles

**Method of Loading:** Cast

**Loading Density:** gm/cc 160

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | Does not exude at 65°C |

Heat of: (d, e)

| | |
|---|---|
| Combustion, cal/gm | 1658* |
| Explosion, cal/gm | 633* |
| Gas Volume, cc/gm | 880* |

*Calculated from composition of mixture.

# Amatol, 50/50

**Composition:**
%

| | |
|---|---|
| Ammonium Nitrate | 50 |
| TNT | 50 |

C/H Ratio

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 95 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 16 |
| Sample Wt, mg | 17 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | Unaffected |

**Rifle Bullet Impact Test:**

| | Trials | % |
|---|---|---|
| Explosions | | 0 |
| Partials | | 0 |
| Burned | | 0 |
| Unaffected | 100 | |

**Explosion Temperature:** °C

Seconds, 0.1 (no cap used)

| | |
|---|---|
| 1 | |
| 5 | Decomposes 265 |
| 10 | |
| 15 | |
| 20 | |

**75°C International Heat Test:**
% Loss in 48 Hrs

**100°C Heat Test:**
% Loss, 1st 48 Hrs
% Loss, 2nd 48 Hrs
Explosion in 100 Hrs

**Flammability Index:**

**Hygroscopicity:** % Nil

**Volatility:**

**Molecular Weight:** 118

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -27 |
| CO % | - 3 |

**Density:** gm/cc Cast 1.59

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$
$n_{25}^{D}$
$n_{30}^{D}$

**Vacuum Stability Test:**
cc/40 Hrs, at

| | |
|---|---|
| 90°C | |
| 100°C | 0.2 |
| 120°C | 1.0 |
| 135°C | |
| 150°C | |

**200 Gram Bomb Sand Test:**
Sand, gm 42.5

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | |
| Lead Azide | 0.20 |
| Tetryl | 0.05 |

**Ballistic Mortar, % TNT:** (a) 124

**Trauzl Test, % TNT:**

**Plate Dent Test:**

| | |
|---|---|
| Method | B |
| Condition | Cast |
| Confined | No |
| Density, gm/cc | 1.55 |
| Brisance, % TNT | 52 |

**Detonation Rate:**

| | | |
|---|---|---|
| Confinement | None | None |
| Condition | Cast | Cast |
| Charge Diameter, in. | 1.0 | 1.0 |
| Density, gm/cc | 1.55 | 1.55 |
| Rate, meters/second | 6430 | 6230 |

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

| | |
|---|---|
| Density, gm/cc | 1.55 |
| Charge Wt, lb | 2.053 |

**Total No. of Fragments:**

| | |
|---|---|
| For TNT | 703 |
| For Subject HE | 630 |

**3 inch HE, M42A1 Projectile, Lot KC-5:**

| | |
|---|---|
| Density, gm/cc | 1.54 |
| Charge Wt, lb | 0.819 |

**Total No. of Fragments:**

| | |
|---|---|
| For TNT | 514 |
| For Subject HE | 385 |

**Fragment Velocity:** ft/sec

At 9 ft

At 25½ ft

Density, gm/cc

**Blast (Relative to TNT):**

**Air:**

| | |
|---|---|
| Peak Pressure | 97 |
| Impulse | 87 |
| Energy | |

**Air, Confined:**

Impulse

**Under Water:**

Peak Pressure

Impulse

Energy 98

**Underground:**

| | |
|---|---|
| Peak Pressure | 104 |
| Impulse | 104 |
| Energy | 104 |

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones (g) |
|---|---|---|
| Hole Volume | 53 | |
| Hole Depth | 69 | |

**Color:** Buff-yellow

**Principal Uses:** Bombs, HE projectiles

**Method of Loading:** Cast

**Loading Density:** gm/cc 1.59

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | Does not exude at 65°C |

| Booster Sensitivity Test: | (a) |
|---|---|
| Condition | Cast |
| Tetryl, gm | 100 |
| Wax, in. for 50% Detonation | 0.60 |
| Density, gm/cc | 1.55 |
| **Heat of:** | (d, e) |
| Combustion, cal/gm | 1990 |
| Explosion, cal/gm | 703* |
| Gas Volume, cc/gm | 855* |

*Calculated from composition of mixture.

| Specific Heat: cal/gm/°C | (i) |
|---|---|
| Temp, 20° to 80°C | 0.383 |

Bomb Drop Test:

T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:

Max Safe Drop, ft 4000-5000

Compatibility with Metals:

Dry - Metals unaffected are zinc, iron, tin, brass, brass tin plated, brass NRC coated, brass shellac coated, nickel aluminum, steel, steel plated with nickel, zinc or tin, stainless steel, Parkerized steel, and steel coated with acid-proof black paint. Metals slightly affected are copper, bronze, lead and copper plated steel.

Preparation:

In preparing amatols the proper granulation of ammonium nitrate is required if the maximum density of the cast amatol is desired. The ammonium nitrate should be dried so as to contain not more than 0.25% moisture. It should be heated to about 90°C before being added to the appropriate weight of molten TNT contained in a melting vessel equipped with an agitator. Continue mixing to insure uniformity and load by pouring into shell or bombs.

Origin:

Developed by the British during World War I in order to conserve TNT.

References:[2]

(a) L. C. Smith and E. H. Eyster, Physical Testing of Explosives, Part III, Miscellaneous Sensitivity Tests, Performance Tests, OSRD Report 5746, 27 December 1945.

(b) Report AC-17/Phys Ex 1.

(c) D. P. McDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(d) Committee of Div 2 and 8, NDRC, Report on HBX and Tritonal, OSRD Report No. 5406, 31 July 1945.

(e) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.

(f) R. W. Drake, Fragment Velocity and Panel Penetration of Several Explosives in Simulated Shells, OSRD Report No. 5622, 2 January 1946.

(g) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Final Report, 18 September 1943, NDRC Contract W-672-ORD-5723.

(h) Also see the following Picatinny Arsenal Technical Reports on Amatols:

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 240 | 681 | 132 | 743 | 364 | 65 | 266 | 1207 | 548 | 549 |
| 350 | 731 | 182 | 1173 | 694 | 425 | 556 | 1457 | 638 | 799 |
| 630 | 901 | 1302 | 1373 | 734 | 695 | 666 | 1797 | 838 | 929 |
| 950 | 1051 | 1352 | 1323 | 874 | 715 | 986 | 1827 | 1098 | 1129 |
| 1300 | 1311 | 1372 | 1493 | 1344 | 735 | 1376 | 2167 | 1148 | 1219 |
| 1530 | 1451 | 1552 | 1783 | | 1145 | 1446 | | 1388 | 1369 |
| | 1651 | | | | 1225 | 1636 | | 1568 | 1559 |
| | | | | | 1345 | 1796 | | 1838 | |
| | | | | | 1455 | | | | |
| | | | | | 1885 | | | | |

(i) TM 9-1910/TO 11A-1-34, Military Explosives, April 1955.

[2]See footnote 1, page 10.

**Composition:**
%

| | |
|---|---|
| Ammonium Nitrate | 22 |
| TNT | 67 |
| Aluminum | 11 |

C/H Ratio

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 91 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 11 |
| Sample Wt, mg | 19 |

**Friction Pendulum Test:**
Steel Shoe
Fiber Shoe

**Rifle Bullet Impact Test:** Trials
%
Explosions
Partials
Burned
Unaffected

**Explosion Temperature:** °C
Seconds, 0.1 (no cap used)
1
5 Decomposes 265
10
15
20

**75°C International Heat Test:**
% Loss in 48 Hrs

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.00 |
| % Loss, 2nd 48 Hrs | 0.10 |
| Explosion in 100 Hrs | None |

**Flammability Index:**

**Hygroscopicity:** %

**Volatility:**

**Molecular Weight:** 102

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -55 |
| CO % | -22 |

**Density:** gm/cc Cast 1.65

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$
$n_{25}^{D}$
$n_{30}^{D}$

**Vacuum Stability Test:**
cc/40 Hrs, at
90°C
100°C
120°C 4.4
135°C
150°C

**200 Gram Bomb Sand Test:**
Sand, gm 47.8

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm
Mercury Fulminate 0.20
Lead Azide
Tetryl

**Ballistic Mortar, % TNT:** (a) 122

**Trauzl Test, % TNT:**

**Plate Dent Test:**
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**Detonation Rate:**
Confinement
Condition
Charge Diameter, in.
Density, gm/cc
Rate, meters/second

# Ammonal

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**

Density, gm/cc 1.65

Charge Wt, lb

**Total No. of Fragments:**

For TNT 655

For Subject HE 550

**Fragment Velocity:** ft/sec

At 9 ft

At 25½ ft

Density, gm/cc

**Blast (Relative to TNT):**

**Air:**

Peak Pressure

Impulse

Energy

**Air, Confined:**

Impulse

**Under Water:**

Peak Pressure

Impulse

Energy

**Underground:**

Peak Pressure

Impulse

Energy

Preparation:

Procedure same as described under Amatols, except aluminum is added to the ammonium nitrate-TNT molten mixture under agitation until uniformity in composition is obtained. Loading is accomplished by pouring into the appropriate projectile.

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:**

**Principal Uses:** Projectile filler

**Method of Loading:** Cast

**Loading Density:** gm/cc 1.65

**Storage:**

Method Dry

Hazard Class (Quantity-Distance) Class 9

Compatibility Group

Exudation

Origin:

Castable mixture developed in United States during World War I.

References:

(a) W. R. Tomlinson, Jr., Physical and Explosive Properties of Military Explosives, PATR No. 1372, 29 November 1943.

(b) Also see the following Picatinny Arsenal Technical Reports on Ammonals: 1108, 1286, 1292, 1308 and 1783.

**Composition:**

| | % | |
|---|---|---|
| N | 35 | $NH_4NO_3$ |
| H | 5 | |
| O | 60 | |
| C/H Ratio | | |

**Molecular Weight:** $(H_4N_2O_3)$ 80

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | +20 |
| CO % | +20 |

**Density:** gm/cc Crystal 1.73

**Melting Point:** °C 170

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^D$ $n_{25}^D$ $n_{30}^D$

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 100+ |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 31 |
| Sample Wt, mg | 17 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | Unaffected |

**Vacuum Stability Test:**

cc/40 Hrs, at

| | |
|---|---|
| 90°C | |
| 100°C | 0.3 |
| 120°C | 0.3 |
| 135°C | |
| 150°C | 0.3 |

**Rifle Bullet Impact Test:**

| | Trials | % |
|---|---|---|
| Explosions | 0 | |
| Partials | 0 | |
| Burned | 0 | |
| Unaffected | 100 | |

**200 Gram Bomb Sand Test:**

| | |
|---|---|
| Sand, gm | Nil |

**Explosion Temperature:** °C

Seconds, 0.1 (no cap used)

| | | |
|---|---|---|
| 1 | | |
| 5 | Ignites | 465 |
| 10 | | |
| 15 | | |
| 20 | | |

**Sensitivity to Initiation:**

Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | |
| Lead Azide | 0.20 |
| Tetryl | 0.25 |

**Ballistic Mortar, % TNT:** (a) 56

**Trauzl Test, % TNT:**

**75°C International Heat Test:** (a)

| | |
|---|---|
| % Loss in 48 Hrs | 0.0 |

**Plate Dent Test:**

| | |
|---|---|
| Method | |
| Condition | |
| Confined | |
| Density, gm/cc | |
| Brisance, % TNT | |

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.74 |
| % Loss, 2nd 48 Hrs | 0.13 |
| Explosion in 100 Hrs | None |

**Detonation Rate:** (b)

| | | |
|---|---|---|
| Confinement | None | Strong |
| Condition | Solid | Liquid |
| Charge Diameter, in. | 1.25 | 4.5 |
| Density, gm/cc | 0.9 | 1.4 |
| Rate, meters/second | 1000 | 2500 |

**Flammability Index:**

**Hygroscopicity:** % 30°C, 90% RH Extreme

**Volatility:** Decomposes at 210°C

**Booster Sensitivity Test:**
- Condition
- Tetryl, gm
- Wax, in. for 50% Detonation
- Wax, gm
- Density, gm/cc

**Heat of:**

| | |
|---|---|
| Combustion, cal/gm | 346 |
| Explosion, cal/gm | 346 |
| Gas Volume, cc/gm | 980 |
| Formation, cal/gm | 1098 |
| Fusion, cal/gm | 18.23 |

**Specific Heat:** cal/gm/°C (e)

| °C | | °C | |
|---|---|---|---|
| -150 | 0.189 | 0 | 0.397 |
| -100 | 0.330 | 50 | 0.414 |
| -50 | 0.364 | 100 | 0.428 |

**Burning Rate:**
cm/sec

**Thermal Conductivity:**
cal/sec/cm/°C $2.9\text{-}3.9 \times 10^{-4}$

**Coefficient of Expansion:**
- Linear, %/°C
- Volume, %/°C

**Hardness, Mohs' Scale:**

**Young's Modulus:**
- E', dynes/cm²
- E, lb/inch²
- Density, gm/cc

**Compressive Strength:** lb/inch²

**Vapor Pressure:**

| °C | (g) mm Mercury |
|---|---|
| 188 | 3.25 |
| 205 | 7.45 |
| 216 | 11.55 |
| 223 | 15.80 |
| 237 | 27.0 |
| 249 | 41.0 |

**Decomposition Equation:**

| | (f) | (h) |
|---|---|---|
| Oxygen, atoms/sec (Z/sec) | $10^{13.8}$ | $10^{12.3}$ |
| Heat, kilocalorie/mole (ΔH, kcal/mol) | 40.5 | 38.3 |
| Temperature Range, °C | 243-261 | 217-267 |
| Phase | Liquid | |

**Armor Plate Impact Test:**

**60 mm Mortar Projectile:**
- 50% Inert, Velocity, ft/sec
- Aluminum Fineness

**500-lb General Purpose Bombs:**

Plate Thickness, inches
- 1
- 1¼
- 1½
- 1¾

**Bomb Drop Test:**

**T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:**

Max Safe Drop, ft

**500-lb General Purpose Bomb vs Concrete:**
- Height, ft
- Trials
- Unaffected
- Low Order
- High Order

**1000-lb General Purpose Bomb vs Concrete:**
- Height, ft
- Trials
- Unaffected
- Low Order
- High Order

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**Fragment Velocity:** ft/sec

At 9 ft

At 25½ ft

Density, gm/cc

**Blast (Relative to TNT):**

**Air:**

Peak Pressure

Impulse

Energy

**Air, Confined:**

Impulse

**Under Water:**

Peak Pressure

Impulse

Energy

**Underground:**

Peak Pressure

Impulse

Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Colorless

**Principal Uses:** Explosive ingredient of mixtures used in bombs or large caliber projectiles

**Method of Loading:** Pressed or cast depending on composition of mixture

**Loading Density:** gm/cc Variable

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 12 |
| Compatibility Group | Group D |
| Exudation | None |

Effect of Temperature on Impact Sensitivity (Chemically pure grade): (b)

| Temp. °C | PA Impact Test 2 Kg Wt, inches |
|---|---|
| 25 | 31 |
| 75 | 28 |
| 100 | 27 |
| 150 | 27 |
| 175 | 12 |

Compatibility with Metals: (a)

In the presence of moisture, ammonium nitrate reacts with copper, iron steel, brass, lead and cadmium.

Entropy: (g)

cal/mol at 25°C 36.0

Solubility of ammonium nitrate, grams in 100 grams (%) of: (e)

| Water | | Alcohol | | Acetic Acid | | Nitric Acid | | | Pyridine | |
|---|---|---|---|---|---|---|---|---|---|---|
| °C | % | °C | % | °C | % | °C | % | % Nitric Acid | °C | % |
| 0 | 118 | 20 | 2.5 | 16.6 | 0.0 | 0 | 45.1 | 30.0 | 25 | ~20-25 |
| 20 | 192 | 40 | 5 | 27.0 | 0.39 | 15 | 73.0 | 21.7 | | |
| 40 | 297 | 60 | 7.5 | 80.9 | 5.8 | 30 | 106 | 20.8 | | |
| 60 | 421 | 78 | 10.5 | 101.0 | 20.7 | 75 | 201 | 31.6 | | |
| 80 | 580 | | | 120.0 | 125 | | | | | |
| 100 | 871 | | | | | | | | | |

Preparation:

Ammonium nitrate is prepared by the neutralization of an aqueous solution of ammonia with nitric acid and evaporation of the solution. The product which is very pure is dried in a graining kettle.

Origin:

First prepared by Glauber in 1659 and first used as an explosive ingredient in 1867 when a Swedish patent was granted to Ohlsson and Norrbin for a composite dynamite.

Destruction by Chemical Decomposition:

Ammonium nitrate is decomposed by strong alkalies with the liberation of ammonia, and by sulfuric acid with the formation of ammonium sulfate and nitric acid.

References:[3]

(a) Departments of the Army and the Air Force TM 9-1910/TO 11a-1-34, Military Explosives, April 1955.

(b) P. F. Macy, T. D. Dudderar, E. F. Reese and L. H. Eriksen, Investigation of Sensitivity of Fertilizer Grade Ammonium Nitrate to Explosion, PATR No. 1658, 11 July 1947.

(c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(d) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(e) International Critical Tables, McGraw-Hill Book Co., N. Y., Land-Bornst.

G. D. Clift and B. T. Federoff, A Manual for Explosives Laboratories, Vol. II, Lefax Society, Inc., Philadelphia, 1943.

(f) R. J. Finkelstein and G. Gamow, Theory of the Detonation Process, NAVORD Report No. 90-46, 20 April 1947.

(g) George Feick, The Dissociation Pressure and Free Energy of Formation of Ammonium Nitrate, Arthur D. Little, Inc., J Am Chem Soc, 76, 5858-60 (1954).

(h) M. A. Cook and M. Taylor Abegg, "Isothermal Decomposition of Explosives", University of Utah, Ind Eng Chem, June 1956, pp. 1090 to 1095.

[3]See footnote 1, page 10.

(i) Also see the following Picatinny Arsenal Technical Reports on Ammonium Nitrate:

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 240 | 681 | 182 | 743 | 364 | 695 | 596 | 907 | 548 | 799 |
| 350 | 731 | 1302 | 1323 | 984 | 1145 | 666 | 1117 | 638 | 1369 |
| 630 | 1051 | 1682 | 1783 | 1094 | 1225 | 676 | 1947 | 938 | 1409 |
| 1290 | 1241 | | 2183 | 1214 | 1455 | 946 | 2167 | 1008 | |
| 1720 | 1311 | | | 1234 | 1635 | 1106 | | 1038 | |
| | 1391 | | | 1304 | 1675 | 1696 | | | |
| | 1431 | | | | 1725 | | | | |

# Ammonium Perchlorate

**Composition:**

| | % |
|---|---|
| Cl | 30.2 |
| N | 11.9 |
| H | 3.4 |
| O | 54.5 |
| C/H Ratio | |

$NH_4ClO_4$

**Molecular Weight:** $(ClH_4NO_4)$ 117.5

**Oxygen Balance:**
- $CO_2$ % +27.3
- CO % +27.3

**Density:** gm/cc 1.95

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^D$ $n_{25}^D$ $n_{30}^D$

**Impact Sensitivity, 2 Kg Wt:**
- Bureau of Mines Apparatus, cm 67
  Sample Wt 20 mg
- Picatinny Arsenal Apparatus, in. 24
  Sample Wt, mg 24

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Snaps |
| Fiber Shoe | Unaffected |

**Vacuum Stability Test:**
cc/40 Hrs, at
- 90°C
- 100°C 0.13
- 120°C 0.20
- 135°C
- 150°C 0.32

**Rifle Bullet Impact Test:** Trials

| | % |
|---|---|
| Explosions | |
| Partials | |
| Burned | |
| Unaffected | |

**200 Gram Bomb Sand Test:**
Sand, gm 6.0

**Explosion Temperature:** °C
Seconds, 0.1 (no cap used)
- 1
- 5 435
- 10
- 15
- 20

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm
- Mercury Fulminate
- Lead Azide 0.20
- Tetryl 0.25

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**75°C International Heat Test:**
% Loss in 48 Hrs

**Plate Dent Test:**
- Method
- Condition
- Confined
- Density, gm/cc
- Brisance, % TNT

**100°C Heat Test:**
- % Loss, 1st 48 Hrs 0.02
- % Loss, 2nd 48 Hrs 0.00
- Explosion in 100 Hrs None

**Detonation Rate:**
- Confinement
- Condition
- Charge Diameter, in.
- Density, gm/cc
- Rate, meters/second

**Flammability Index:**

**Hygroscopicity:** %

**Volatility:**

# Ammonium Perchlorate

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**Fragment Velocity:** ft/sec

At 9 ft

At 25½ ft

Density, gm/cc

**Blast (Relative to TNT):**

**Air:**

Peak Pressure

Impulse

Energy

**Air, Confined:**

Impulse

**Under Water:**

Peak Pressure

Impulse

Energy

**Underground:**

Peak Pressure

Impulse

Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Colorless

**Principal Uses:** Explosive ingredient of mixtures used in pyrotechnics and as projectile filler

**Method of Loading:** Pressed or cast depending on composition of mixture

**Loading Density:** gm/cc Variable

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | |
| Exudation | None |

Solubility in Water
gm/100 cc saturated solution:

| | |
|---|---|
| 0°C | 12 |
| 25°C | 20 |
| 60°C | 39 |
| 100°C | 88 |

Preparation:

The perchlorates are prepared by the action of the acid on a suitable base; by the thermal decomposition of certain chlorates; and by the electrolysis of chlorates (see origin).

Heat of:

Formation, cal/gm 665

Origin: (c)

E. Mitscherlich first prepared, in 1832, crystals of ammonium perchlorate from barium perchlorate and ammonium sulfate (Pogg Ann 25, 300). T. Schlosing treated a hot solution of sodium perchlorate with ammonium chloride, and on cooling, crystals of ammonium perchlorate were obtained (Comp rend, 73, 1269, [1871]). U. Alvisi treated a mixture of 76 parts of ammonium nitrate with 213 parts of sodium perchlorate, and obtained a crop of small crystals of ammonium perchlorate which were purified by recrystallization from hot water (German Patent, 103,993, 1898). A. Miolati mixed magnesium or calcium perchlorate with ammonium chloride and crystals of ammonium perchlorate deposited from the solution of very soluble magnesium or calcium chloride (German Patent, 112, 682, 1899).

References:[4]

(a) W. R. Tomlinson, Jr., Physical and Explosive Properties of Military Explosives, PATR No. 1372, 29 November 1943.

(b) T. L. Davis, The Chemistry of Powder and Explosives, John Wiley and Sons, Inc., New York, 1943.

(c) J. W. Mellor, A Comprehensive Treatise on Inorganic and Theoretical Chemistry, Vol. II, Longmanns, Green and Co., London, 1922, p. 396.

(d) Also see the following Picatinny Arsenal Technical Reports on Ammonium Perchlorate:

| 0 | 1 | 3 | 4 | 5 | 6 | 9 |
|---|---|---|---|---|---|---|
| 100 | 321 | 843<br>1783 | 354<br>604<br>854 | 1095<br>1725<br>2205 | 1726 | 1049<br>1969 |

[4]See footnote 1, page 10.

**Composition:**
%

| | |
|---|---|
| Barium nitrate | 67 |
| TNT | 33 |

C/H Ratio

**Impact Sensitivity, 2 Kg Wt:**
Bureau of Mines Apparatus, cm 35
Sample Wt 20 mg
Picatinny Arsenal Apparatus, in. 11
Sample Wt, mg 24

**Friction Pendulum Test:**
Steel Shoe
Fiber Shoe

**Rifle Bullet Impact Test:** Trials
%
Explosions
Partials
Burned
Unaffected

**Explosion Temperature:** °C
Seconds, 0.1 (no cap used)
1
5 Ignites 385
10
15
20

**75°C International Heat Test:**
% Loss in 48 Hrs

**100°C Heat Test:**
% Loss, 1st 48 Hrs
% Loss, 2nd 48 Hrs
Explosion in 100 Hrs

**Flammability Index:**

**Hygroscopicity:** %
30°C, 90% RH 0.00

**Volatility:**

**Molecular Weight:** 125

**Oxygen Balance:**
$CO_2$ % -3
CO % +13

**Density:** gm/cc Cast 2.55

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$
$n_{25}^{D}$
$n_{30}^{D}$

**Vacuum Stability Test:**
cc/40 Hrs, at
90°C
100°C
120°C
135°C
150°C

**200 Gram Bomb Sand Test:**
Sand, gm 26.8

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm
Mercury Fulminate
Lead Azide 0.20
Tetryl 0.10

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**Plate Dent Test:** (a) 73/27
Method B
Condition Cast
Confined No
Density, gm/cc 2.52
Brisance, % TNT 61

**Detonation Rate:**
Confinement
Condition
Charge Diameter, in.
Density, gm/cc
Rate, meters/second

**Booster Sensitivity Test:**

| | |
|---|---|
| Condition | Cast |
| Tetryl, gm | 100 |
| Wax, in. for 50% Detonation | 0.32 |
| Wax, gm | |
| Density, gm/cc | 2.55 |

**Heat of:**

Combustion, cal/gm

Explosion, cal/gm

Gas Volume, cc/gm

Formation, cal/gm

Fusion, cal/gm 75/25 Baratol 2.8 (d)

**Specific Heat:** cal/gm/°C (d) 75/25 Baratol

| °C | | °C | |
|---|---|---|---|
| -75 | 0.152 | 75 | 0.280 |
| 0 | 0.147 | 85 | 0.213 |
| 25 | 0.180 | 90 | 0.201 |
| 50 | 0.229 | 100 | 0.171 |

**Burning Rate:**

cm/sec

**Thermal Conductivity:**

cal/sec/cm/°C

**Coefficient of Expansion:**

Linear, %/°C

Volume, %/°C

**Hardness, Mohs' Scale:**

**Young's Modulus:**

E', dynes/cm²

E, lb/inch²

Density, gm/cc

**Compressive Strength:** lb/inch²

**Vapor Pressure:**

°C mm Mercury

**Decomposition Equation:**

Oxygen, atoms/sec (Z/sec)

Heat, kilocalorie/mole (ΔH, kcal/mol)

Temperature Range, °C

Phase

**Armor Plate Impact Test:**

**60 mm Mortar Projectile:**

50% Inert, Velocity, ft/sec

Aluminum Fineness

**500-lb General Purpose Bombs:**

Plate Thickness, inches

1

1¼

1½

1¾

**Bomb Drop Test:**

**T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:**

Max Safe Drop, ft

**500-lb General Purpose Bomb vs Concrete:**

Height, ft

Trials

Unaffected

Low Order

High Order

**1000-lb General Purpose Bomb vs Concrete:**

Height, ft

Trials

Unaffected

Low Order

High Order

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:**

**Principal Uses:** Bomb filler

**Method of Loading:** Cast

**Loading Density:** gm/cc 2.55

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | |

Preparation:

The appropriate weight of barium nitrate heated to about 90°C is added to molton TNT contained in a melting vessel equipped with an agitator. Continue mixing until uniform, and load by pouring at the lowest practical temperature.

Origin:

Baratol, an explosive containing barium nitrate and TNT, the proportions varied to suit the required purposes, was developed during World War I.

References:[5]

(a) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(b) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(c) Also see the following Picatinny Arsenal Technical Reports on Baratol:

| 0 | 3 | 6 | 8 |
|---|---|---|---|
| 2010 | 1783 | 2226 | 2138 |
| 2160 | 2233 | | |

(d) C. Lenchitz, W. Beach and R. Valicky, Enthalpy Changes, Heat of Fusion and Specific Heat of Basic Explosives, PATR No. 2504, January 1959.

[5]See footnote 1, page 10.

**Composition:**

| | % |
|---|---|
| Barium nitrate | 50 |
| TNT | 35 |
| Aluminum | 15 |

C/H Ratio

**Impact Sensitivity, 2 Kg Wt:**
Bureau of Mines Apparatus, cm 30
Sample Wt 20 mg
Picatinny Arsenal Apparatus, in. 12
Sample Wt, mg 22

**Friction Pendulum Test:**
Steel Shoe
Fiber Shoe

**Rifle Bullet Impact Test:** Trials

| | % |
|---|---|
| Explosions | |
| Partials | |
| Burned | |
| Unaffected | |

**Explosion Temperature:** °C
Seconds, 0.1 (no cap used)

| | | |
|---|---|---|
| 1 | | |
| 5 | Ignites | 345 |
| 10 | | |
| 15 | | |
| 20 | | |

**75°C International Heat Test:**
% Loss in 48 Hrs

**100°C Heat Test:**
% Loss, 1st 48 Hrs
% Loss, 2nd 48 Hrs
Explosion in 100 Hrs

**Flammability Index:**

**Hygroscopicity:** %

**Volatility:**

**Molecular Weight:** 111

**Oxygen Balance:**
$CO_2$ % -24
CO % - 7

**Density:** gm/cc 2.32

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$
$n_{25}^{D}$
$n_{30}^{D}$

**Vacuum Stability Test:**
cc/40 Hrs, at
90°C
100°C
120°C
135°C
150°C

**200 Gram Bomb Sand Test:**
Sand, gm 39.8

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm
Mercury Fulminate
Lead Azide 0.20
Tetryl 0.10

**Ballistic Mortar, % TNT:** (a) 96

**Trauzl Test, % TNT:**

**Plate Dent Test:**
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**Detonation Rate:** (b)

| | |
|---|---|
| Confinement | None |
| Condition | Cast |
| Charge Diameter, in. | 1.0 |
| Density, gm/cc | 2.32 |
| Rate, meters/second | 5450 |

# Baronal

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:**

**Principal Uses:** Bomb filler

**Method of Loading:** Cast

**Loading Density:** gm/cc 232

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | |

Preparation:

Procedure same as described under Baratol except aluminum is added to the barium nitrate-TNT molton mixture under agitation until uniformity in comparison is obtained.

Booster Sensitivity Test:

| | (c) |
|---|---|
| Condition | Cast |
| Tetryl, gm | 100 |
| Wax, in. for 50% Detonation | 0.86 |
| Density, gm/cc | 2.32 |

Heat of:

| | |
|---|---|
| Combustion, cal/gm | 2099 |
| Explosion, cal/gm | 1135 |
| Gas Volume, cc/gm | 410 |

Baronal

References:[6]

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) G. H. Messerly, The Rate of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.

M. D. Hurwitz, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1946.

(c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(d) Arthur D. Little Report, Study of Pure Explosive Compounds, Part III, Correlation of Composition of Mixture with Performance, Contract No. DA-19-020-ORD-12, 1 May 1950.

(e) S. J. Lowell, Propagation of Detonation in Long and Narrow Columns of Explosives, PATR No. 2138, February 1955.

[6]See footnote 1, page 10.

# Black Powder

**Composition:**

| | % |
|---|---|
| Potassium nitrate | 74.0 |
| Sulfur | 10.4 |
| Charcoal | 15.6 |
| C/H Ratio | |

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 32 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 16 |
| Sample Wt, mg | 16 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Snaps |
| Fiber Shoe | Unaffected |

**Rifle Bullet Impact Test:**

| | Trials % |
|---|---|
| Explosions | |
| Partials | |
| Burned | |
| Unaffected | |

**Explosion Temperature:**

| Seconds, | | °C |
|---|---|---|
| 0.1 | (no cap used) | 510 |
| 1 | | 490 |
| 5 | Ignites | 427 |
| 10 | | 356 |
| 15 | | |
| 20 | | |

**75°C International Heat Test:**

| | |
|---|---|
| % Loss in 48 Hrs | 0.31 |

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | |
| % Loss, 2nd 48 Hrs | |
| Explosion in 100 Hrs | |

**Flammability Index:**

**Hygroscopicity:** %

| | |
|---|---|
| 26°C, 75% RH | 0.75 |
| 25°C, 90% RH | 1.91 |
| 30°C, 90% RH | 2.51 |

**Volatility:**

**Molecular Weight:** 84

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -22 |
| CO % | - 2 |

**Density:** gm/cc Variable

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Vacuum Stability Test:**

| cc/40 Hrs, at | |
|---|---|
| 90°C | |
| 100°C | 0.5 |
| 120°C | 0.9 |
| 135°C | |
| 150°C | |

**200 Gram Bomb Sand Test:**

| | |
|---|---|
| Sand, gm | 8 |

**Sensitivity to Initiation:**

| | |
|---|---|
| Minimum Detonating Charge, gm | |
| Mercury Fulminate | |
| Lead Azide | |
| Tetryl | |

Sensitive to igniting fuse

**Ballistic Mortar, % TNT:** 50

**Trauzl Test, % TNT:** (a) 10

**Plate Dent Test:**

| | |
|---|---|
| Method | |
| Condition | |
| Confined | |
| Density, gm/cc | |
| Brisance, % TNT | |

**Detonation Rate:**

| | |
|---|---|
| Confinement | |
| Condition | |
| Charge Diameter, in. | |
| Density, gm/cc | 1.6 |
| Rate, meters/second | 400 |

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

Initiating Efficiency:

Grams Required to Initiate

| | |
|---|---|
| Igniter Comp K-31 | 2.0 |
| Igniter Comp K-29 | 2.3 |

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Black

**Principal Uses:** 1. Igniter powder
2. Time rings (fuzes)

**Method of Loading:** 1. Loose (granulated)
2. Pressed

**Loading Density:** gm/cc

| psi x $10^3$ | | | | | |
|---|---|---|---|---|---|
| 25 | 50 | 60 | 65 | 70 | 75 |
| 1.74 | 1.84 | 1.86 | 1.87 | 1.88 | 1.89 |

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group 0 |
| Exudation | None |

100°C Vacuum Stability Test, cc gas/40 hrs:

| | |
|---|---|
| Initial Value | 0.5 |
| After 2 hours at 65°C | 0.86 |
| After 2 hours at 65°C, 75% RH | 1.46 |

Sensitivity to Electrostatic Discharge, Joules: (b)

| | |
|---|---|
| Unconfined | >12.5 |
| Confined | 0.8 |

Compatibility with Metals:

Dry - Compatible with all metals when moisture content is less than 0.20%.

Wet - Attacks all common metals except stainless steel.

Heat of:

| | |
|---|---|
| Explosion, cal/gm | 684 |
| Gas Volume, cc/gm | 271 |

Preparation:

Willow or alder charcoal, flour of sulphur and 2-3% of water are placed in a tumbling barrel and mixed for a short period (about 1/2 hour). The mixture is transferred to a "wheel mill" and crystalline potassium nitrate containing 3-4% moisture is added and the mixture is incorporated for several hours. During the incorporation period the mixture is kept damp (2-3% moisture) by adding water at intervals. The mill cake is then pressed at 6000 psi between aluminum plates. The pressed cakes are broken up between rubber or wood rolls. The material is screened and the various particle sizes are separated as desired. The screened material is then transferred to canvas trays and dried in hot air ovens at 60°C. If it is desired to glaze the black powder, the material before drying is polished by rotation in a tumbling barrel to give it a smooth surface. It is next screened to remove the dust. The smooth particles are then placed in a wooden barrel and rotated with graphite. The material is again screened to remove the excess graphite, and dried. Material finer than #40 U. S. Sieve is not graphited.

## WARNING

The batches of black powder must be of sufficient size to cover the bed of the "wheel mill." If the wheels run off on the bare bed, explosions usually result.

Origin:

The exact date of the discovery of black powder is unknown. Historians attribute its discovery to the Chinese, Hindus or Arabs. The Greeks used it during the 7th Century. Marcus Graecus in the 9th Century and Roger Bacon in the 13th Century described compositions similar to the present powder. Beginning with the 16th Century, the composition of black powder containing potassium nitrate, charcoal and sulfur has remained unchanged with respect to the proportionality (75/15/10) of the ingredients.

Destruction by Chemical Decomposition:

Black powder can be desensitized by leaching with water to dissolve the potassium nitrate. The washings must be disposed of separately because the residue of sulfur and charcoal is combustible but not explosive.

References:[7]

(a) Ph. Naoum, Nitroglycerine and Nitroglycerine Explosives, Baltimore, 1928.

(b) F. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Department of the Interior, Bureau of Mines RI 3852, 1946.

(c) Also see the following Picatinny Arsenal Technical Reports on Black Powder:

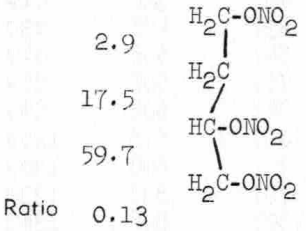
[7] See footnote 1, page 10.

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 250 | 91 | 222 | 163 | 354 | 65 | 56 | 347 | 188 | 379 |
| 710 | 471 | 272 | 363 | 454 | 415 | 176 | 407 | 318 | 819 |
| 850 | 661 | 322 | 453 | 544 | 545 | 356 | 437 | 428 | 839 |
| 1010 | 901 | 472 | 843 | 554 | 605 | 686 | 547 | 558 | 849 |
| 1450 | 1111 | 492 | 1043 | 574 | 1145 | 746 | 757 | 598 | 859 |
| | 1241 | 582 | 1153 | 594 | 1275 | 1256 | 847 | 608 | 899 |
| | 1451 | 762 | 1243 | 654 | 1815 | 1316 | 1097 | 618 | 1259 |
| | 1541 | 872 | 1333 | 664 | 1885 | 1536 | 1737 | 698 | 1309 |
| | 1711 | 1022 | 1493 | 774 | 1905 | 1576 | 1797 | 838 | 1339 |
| | 1911 | 1622 | 1583 | 844 | 1915 | 1586 | 1807 | 898 | 1349 |
| | 1951 | 1712 | 1643 | 1114 | | 1946 | 1827 | 1068 | 1589 |
| | 2051 | 1802 | 1813 | 1154 | | | | 1388 | 1739 |
| | | 1912 | 1843 | 1244 | | | | 1528 | 1869 |
| | | | 1973 | 1504 | | | | 1778 | 1889 |
| | | | | | | | | 1808 | |
| | | | | | | | | 1838 | |
| | | | | | | | | 1928 | |
| | | | | | | | | 2178 | |

# 1,2,4-Butanetriol Trinitrate (BTTN) Liquid

**Composition:**

| | % |
|---|---|
| C | 19.9 |
| H | 2.9 |
| N | 17.5 |
| O | 59.7 |
| C/H Ratio | 0.13 |



**Molecular Weight:** $(C_4H_7N_3O_9)$ 241

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -17 |
| CO % | 10 |

**Density:** gm/cc Liquid 1.52

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^D$ 1.4738; $n_{25}^D$; $n_{30}^D$

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 58 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | ≦1 |
| Sample Wt, mg | |

**Friction Pendulum Test:**

Steel Shoe

Fiber Shoe

**Vacuum Stability Test:**

cc/40 Hrs, at

| | |
|---|---|
| 90°C | |
| 100°C | 2.33 |
| 120°C | |
| 135°C | |
| 150°C | |

**Rifle Bullet Impact Test:** Trials

| | % |
|---|---|
| Explosions | |
| Partials | |
| Burned | |
| Unaffected | |

**200 Gram Bomb Sand Test:**

Sand, gm 48.6

**Explosion Temperature:** °C

Seconds, 0.1 (no cap used)

| | | |
|---|---|---|
| 1 | | |
| 5 | Decomposes | 230 |
| 10 | | |
| 15 | | |
| 20 | | |

**Sensitivity to Initiation:**

Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | |
| Lead Azide | 0.20 |
| Tetryl | 0.10 |

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**75°C International Heat Test:**

% Loss in 48 Hrs

**Plate Dent Test:**

Method

Condition

Confined

Density, gm/cc

Brisance, % TNT

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 1.5 |
| % Loss, 2nd 48 Hrs | 1.2 |
| Explosion in 100 Hrs | None |

**Flammability Index:**

**Detonation Rate:**

Confinement

Condition

Charge Diameter, in.

Density, gm/cc

Rate, meters/second

**Hygroscopicity:** % (a)

100°F, 95% RH, 24 hrs 0.14

**Volatility:**

60°C, $mg/cm^2/hr$ 46

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**Fragment Velocity:** ft/sec

At 9 ft

At 25½ ft

Density, gm/cc

**Blast (Relative to TNT):**

**Air:**

Peak Pressure

Impulse

Energy

**Air, Confined:**

Impulse

**Under Water:**

Peak Pressure

Impulse

Energy

**Underground:**

Peak Pressure

Impulse

Energy

| Heat of: | (a) |
|---|---|
| Combustion, cal/gm | 2168 |
| Explosion, cal/gm | 1457 |
| Gas Volume, cc/gm | 840 |

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Yellow oil

**Principal Uses:** Explosive plasticizer for nitrocellulose

**Method of Loading:**

**Loading Density:** gm/cc 1.52

**Storage:**

Method

Hazard Class (Quantity-Distance)

Compatibility Group

Exudation

| Solubility in Water, gm/100 gm, at: | (a) |
|---|---|
| 20°C | 0.08 |
| 60°C | 0.15 |
| Solubility of Water in, gm/100 gm: | (a) 0.04 |
| Solubility, gm/100 gm, at 25°C, in: | |
| Ether | ∞ |
| Alcohol | ∞ |
| 2:1 Ether:Alcohol | ∞ |
| Acetone | ∞ |
| Viscosity, centipoises: | (a) |
| Temp, 25°C | 59 |

## 1,2,4-Butanetriol Trinitrate (BTTN) Liquid

Preparation (Laboratory Procedure):

To a cooled mixture of 73.8 gm of 100% nitric acid, 46.2 gms of 106.2% sulfuric acid and 60.0 gm of 96.1% sulfuric acid, 30 gms of the original (or redistilled) 1,2,4-butanetriol was added dropwise with agitation for a period of thirty minutes. The temperature of the reaction mixture was kept at 0°-5°C. When the agitation was completed, stirring was continued for one and one-half hours. The mixture was poured into ice water, and the resulting oil suspension was extracted with three 100 milliliter portions of ether. The combined ether extracts were washed with water, then with a 5% sodium bicarbonate solution and finally with water. The neutralized extract was dried with anhydrous calcium chloride and then the ether was evaporated. The yellow oil was dried in a vacuum desiccator over anhydrous calcium chloride until the material was brought to constant weight.

Origin:

1,2,4-butanetriol was first synthesized by Wagner and Ginsberg in 1894 by oxidizing allyl carbinol with potassium permanganate under mild conditions (Ber 27, 2437). Recently the U. S. Rubber Laboratory, under the direction of P. Tawney, devised a new synthesis carried out with allyl acetate and formaldehyde to give 1,2,4-butane triacetate which was readily hydrolysed to butanetriol (U. S. Rubber Company Quarterly Report, May 1948). Working with pure 1,2,4-butanetriol prepared by an improved technique of the Wagner method, the U. S. Naval Laboratory in 1948 nitrated the butanetriol on a laboratory and a pilot plant scale (Reference a).

References:[8]

(a) J. A. Gallaghan, F. Macri, J. Bednarik, and F. McCollum, The Synthesis of 1,2,4-Butanetriol and the Evaluation of Its Trinitrate, U. S. Naval Powder Factory Technical Report No. 19, 10 September 1948.

(b) Also see the following Picatinny Arsenal Technical Reports on Butanetriol Trinitrate: 1755 and 1786.

[8]See footnote 1, page 10.

## Composition A-3

**Composition:**

| | % |
|---|---|
| RDX | 91 |
| Wax | 9 |
| C/H Ratio | |

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 100+ |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 16 |
| Sample Wt, mg | 17 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | Unaffected |

**Rifle Bullet Impact Test:**

| | Trials % |
|---|---|
| Explosions | 0 |
| Partials | 0 |
| Burned | 0 |
| Unaffected | 100 |

**Explosion Temperature:** °C

| Seconds, 0.1 (no cap used) | | |
|---|---|---|
| 1 | | |
| 5 | Decomposes | 250 |
| 10 | | |
| 15 | | |
| 20 | | |

**75°C International Heat Test:**
% Loss in 48 Hrs

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.15 |
| % Loss, 2nd 48 Hrs | 0.15 |
| Explosion in 100 Hrs | None |

**Flammability Index:** 195

**Hygroscopicity:** % 30°C, 90% RH 0.0

**Volatility:** 50°C, 15 days 0.03

**Molecular Weight:** 227

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -48 |
| CO % | -23 |

**Density:** gm/cc 12,000 psi 1.65

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$
$n_{25}^{D}$
$n_{30}^{D}$

**Vacuum Stability Test:**

| cc/40 Hrs, at | |
|---|---|
| 90°C | |
| 100°C | 0.3 |
| 120°C | 0.6 |
| 135°C | |
| 150°C | |

**200 Gram Bomb Sand Test:**
Sand, gm 51.5

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | 0.22* |
| Lead Azide | 0.25* |
| Tetryl | |

* Alternative initiating charges

**Ballistic Mortar, % TNT:** (a) 135

**Trauzl Test, % TNT:**

**Plate Dent Test:**

| | (b) | |
|---|---|---|
| Method | B | B |
| Condition | Pressed | Pressed |
| Confined | No | No |
| Density, gm/cc | 1.61 | 1.20 |
| Brisance, % TNT | 126 | 75 |

**Detonation Rate:** (c)

| | |
|---|---|
| Confinement | None |
| Condition | Pressed |
| Charge Diameter, in. | 1.0 |
| Density, gm/cc | 1.59 |
| Rate, meters/second | 8100 |

## Composition A-3

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

| | |
|---|---|
| Density, gm/cc | 1.62 |
| Charge Wt, lb | 2.102 |

**Total No. of Fragments:**

| | |
|---|---|
| For TNT | 703 |
| For Subject HE | 1138 |

**3 inch HE, M42A1 Projectile, Lot KC-5:**

| | |
|---|---|
| Density, gm/cc | 1.64 |
| Charge Wt, lb | 0.861 |

**Total No. of Fragments:**

| | |
|---|---|
| For TNT | 514 |
| For Subject HE | 710 |

**Fragment Velocity:** ft/sec

| | |
|---|---|
| At 9 ft | 2800 |
| At 25½ ft | 2530 |
| Density, gm/cc | 1.61 |

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** White-buff

**Principal Uses:** HE, SAP, AP projectiles; Shaped Charges

**Method of Loading:** Pressed

| **Loading Density:** gm/cc | psi x $10^3$ |
|---|---|
| 3 | 12 |
| 1.47 | 1.65 |

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |

Exudation Does not exude at 65°C when waxes melting sharply at or above 75°C are used.

Preparation:

A water slurry of RDX is heated to 100°C with agitation. Wax and a wetting agent are added and the mixture, under agitation, is cooled below the melting point of the wax. The wax coated RDX is collected on a filter and air dried at 75°C.

Effect of Temperature on Rate of Detonation: (e)

| 16 hrs at, °C | -54 | 21 |
|---|---|---|
| Density, gm/cc | 1.51 | 1.51 |
| Rate, m/sec | 7600 | 7620 |

Booster Sensitivity Test: (d)

| | |
|---|---|
| Condition | Pressed |
| Tetryl, gm | 100 |
| Wax, in. for 50% Detonation | 1.70 |
| Density, gm/cc | 1.62 |

Heat of:

| | |
|---|---|
| Combustion, cal/gm | 1210 |

## Composition A-3

Compatibility with Metals:

Dry - Aluminum, stainless steel, mild steel, mild steel coated with acid-proof black paint and mild steel plated with nickel or zinc are unaffected. Copper, magnesium, magnesium-aluminum alloy, brass and mild steel plated with cadmium or copper are slightly affected.

Wet - Stainless steel is unaffected. Copper, aluminum, magnesium, brass, mild steel, mild steel coated with acid-proof black paint and mild steel plated with copper, cadmium, nickel or zinc are slightly affected.

Origin:

Developed by the British during World War II as RDX and beeswax. Subsequent changes in the United States replaced beeswax with synthetic waxes, changed the granulation of RDX and improved the method of manufacture.

Destruction by Chemical Decomposition:

RDX Composition A-3 (RDX/wax, 91/9) is decomposed by adding it slowly to 25 times its weight of boiling 5% sodium hydroxide. Boiling of the solution is continued for one-half hour.

References:[9]

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(c) G. H. Messerly, The Rate of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.

M. D. Hurwitz, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1946.

(d) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, dated 15 June 1949.

(e) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Different Temperatures, PATR No. 2383, November 1956.

(f) Also see the following Picatinny Arsenal Technical Reports on RDX Composition A-3:

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1380 | 1451 | 1492 | 1493 | 1424 | 1325 | 1556 | 1687 | 1338 | 1639 |
| 1910 | 1761 | 2112 | | 1614 | 1585 | 1936 | 1787 | 1388 | 2179 |
| | | | | 1634 | 1595 | | 1797 | 1728 | |
| | | | | 2154 | 1715 | | | 1838 | |
| | | | | | 1885 | | | | |
| | | | | | 2235 | | | | |

[9]See footnote 1, page 10.

# Composition B

**Composition:**
%

| | |
|---|---|
| RDX | 60 |
| TNT | 40 |
| Wax, added | 1 |

C/H Ratio

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 75 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 14 |
| Sample Wt, mg | 19 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | Unaffected |

**Rifle Bullet Impact Test:**

| | Trials | % |
|---|---|---|
| Explosions | 3 | |
| Partials | 13 | |
| Burned | 4 | |
| Unaffected | 80 | |

**Explosion Temperature:**

| | °C |
|---|---|
| Seconds, 0.1 (no cap used) | 526 |
| 1 | 368 |
| 5 Decomposes | 278 |
| 10 | 255 |
| 15 | > 250 |
| 20 | > 250 |

**75°C International Heat Test:**
% Loss in 48 Hrs

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.2 |
| % Loss, 2nd 48 Hrs | 0.2 |
| Explosion in 100 Hrs | None |

**Flammability Index:** 177

**Hygroscopicity:** % 30°C, 90% RH 0.02

**Volatility:**

**Molecular Weight:** 224

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -43 |
| CO % | 10 |

**Density:** gm/cc Cast 1.65

**Melting Point:** °C (1) 78-80

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Vacuum Stability Test:**
cc/40 Hrs, at

| | |
|---|---|
| 90°C | |
| 100°C | 0.7 |
| 120°C | 0.9 |
| 135°C | |
| 150°C | 11+ |

**200 Gram Bomb Sand Test:**
Sand, gm 54.0

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | 0.22* |
| Lead Azide | 0.20* |
| Tetryl | |

* Alternative initiating charges

**Ballistic Mortar, % TNT:** (a) 133

**Trauzl Test, % TNT:** (b) 130

**Plate Dent Test:** (c)

| | |
|---|---|
| Method | B |
| Condition | Cast |
| Confined | No |
| Density, gm/cc | 1.71 |
| Brisance, % TNT | 132 |

**Detonation Rate:**

| | |
|---|---|
| Confinement | None |
| Condition | Cast |
| Charge Diameter, in. | 1.0 |
| Density, gm/cc | 1.68 |
| Rate, meters/second | 7840 |

**Booster Sensitivity Test:** (d)

| | |
|---|---|
| Condition | Cast |
| Tetryl, gm | 100 |
| Wax, in. for 50% Detonation | 1.40 |
| Wax, gm | |
| Density, gm/cc | 1.69 |

**Heat of:** (e)

| | | |
|---|---|---|
| Combustion, cal/gm | | 2790 |
| Explosion, cal/gm | | 1240 |
| Gas Volume, cc/gm | | |
| Formation, cal/gm | | |
| Fusion, cal/gm | (1) | 8.0 |

**Specific Heat:** cal/gm/°C (1)

| °C | | °C | |
|---|---|---|---|
| -75 | 0.235 | 75 | 0.376 |
| 0 | 0.220 | 85 | 0.354 |
| 25 | 0.254 | 90 | 0.341 |
| 50 | 0.305 | 100 | 0.312 |

**Burning Rate:**
cm/sec

**Thermal Conductivity:**
cal/sec/cm/°C

**Coefficient of Expansion:**
Linear, %/°C

Volume, %/°C

**Hardness, Mohs' Scale:**

**Young's Modulus:**
E', dynes/cm²
E, lb/inch²
Density, gm/cc

**Compressive Strength:** lb/inch² (b) 1610-2580
Density, gm/cc 1.68

**Vapor Pressure:**
°C mm Mercury

**Decomposition Equation:**
Oxygen, atoms/sec (Z/sec)
Heat, kilocalorie/mole (ΔH, kcal/mol)
Temperature Range, °C
Phase

**Armor Plate Impact Test:** (e)

**60 mm Mortar Projectile:**
50% Inert, Velocity, ft/sec 209
Aluminum Fineness

**500-lb General Purpose Bombs:**

Plate Thickness, inches

| | Trials | % Inert |
|---|---|---|
| 1 | 4 | 100 |
| 1¼ | 6 | 50 |
| 1½ | 2 | 0 |
| 1¾ | 0 | |

**Bomb Drop Test:**

**T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:**

Max Safe Drop, ft

**500-lb General Purpose Bomb vs Concrete:**

| | No Seal | Seal |
|---|---|---|
| Height, ft | 4000 | 4000 |
| Trials | 65 | 39 |
| Unaffected | 58 | 36 |
| Low Order | 2 | 2 |
| High Order | 5 | 1 |

**1000-lb General Purpose Bomb vs Concrete:**

Height, ft
Trials
Unaffected
Low Order
High Order

# Composition B

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

| | |
|---|---|
| Density, gm/cc | 1.65 |
| Charge Wt, lb | 2.187 |

**Total No. of Fragments:**

| | |
|---|---|
| For TNT | 703 |
| For Subject HE | 998 |

**3 inch HE, M42A1 Projectile, Lot KC-5:**

| | |
|---|---|
| Density, gm/cc | 1.67 |
| Charge Wt, lb | 0.882 |

**Total No. of Fragments:**

| | |
|---|---|
| For TNT | 514 |
| For Subject HE | 701 |

**Fragment Velocity:** ft/sec

| | |
|---|---|
| At 9 ft | 2940 |
| At 25½ ft | 2680 |
| Density, gm/cc | 1.68 |

**Blast (Relative to TNT):** (f)

**Air:**

| | |
|---|---|
| Peak Pressure | 110 |
| Impulse | 110 |
| Energy | 116 |

**Air, Confined:**

| | |
|---|---|
| Impulse | 75 |

**Under Water:**

| | |
|---|---|
| Peak Pressure | 110 |
| Impulse | 108 |
| Energy | 121 |

**Underground:**

| | |
|---|---|
| Peak Pressure | 104 |
| Impulse | 97 |
| Energy | |
| Crater radius cubed | 107 |

**Shaped Charge Effectiveness, TNT = 100:**

| | (g) Glass Cones | (h) Steel Cones |
|---|---|---|
| Hole Volume | 178 | 162 |
| Hole Depth | 125 | 148 |

**Color:** Yellow-brown

**Principal Uses:** Fragmentation bombs, HE projectiles, grenades, shaped charges

**Method of Loading:** Cast

**Loading Density:** gm/cc 1.68

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |

Exudation Very slight when stored at 71°C

Origin:

RDX Composition B was developed by the British between World War I and World War II. It was standardized by the United States early in World War II.

Effect of Temperature on Rate of Detonation: (i)

| | | |
|---|---|---|
| 16 hrs at, °C | -54 | 24 |
| Density, gm/cc | 1.69 | 1.69 |
| Rate, m/sec | 7720 | 7660 |

Bulk Modulus at Room Temperature (25°-30°C): (j)

| % Wax in Comp B | 1 | 2 | 3 |
|---|---|---|---|
| Dynes/cm$^2$ x $10^{-10}$ | 5.10 | 3.56 | 2.34 |
| Density, gm/cc | 1.72 | 1.70 | 1.68 |

Viscosity, poises:

| | |
|---|---|
| Temp, 83°C | 3.1 |
| 95°C | 2.7 |

## Composition B

Compatibility with Metals:

Dry - Magnesium, aluminum, magnesium-aluminum alloy, mild steel, stainless steel, mild steel coated with acid-proof black paint and mild steel plated with zinc or nickel are unaffected. Copper, brass and mild steel plated with copper or cadmium are slightly affected.

Wet - Aluminum and stainless steel are unaffected. Copper, brass, mild steel, mild steel coated with acid-proof black paint and mild steel plated with cadmium, copper, nickel or zinc are slightly affected. Magnesium and magnesium-aluminum alloy are more heavily affected.

Preparation:

Water wet RDX is added slowly with stirring to molten TNT melted in a steam-jacketed kettle at a temperature of 100°C. Some water is poured off and heating and stirring are continued until all moisture is evaporated. Wax is then added and when thoroughly mixed, the composition is cooled to a satisfactory pouring temperature. It is cast directly into ammunition components or in the form of chips when Composition B is to be stored.

Destruction by Chemical Decomposition:

RDX Composition B is decomposed in 12 parts by weight of technical grade acetone heated to 45°C. While this is stirred vigorously, there is added 12 parts of a solution, heated to 70°C, of 1 part sodium sulfide ($Na_2S \cdot 9H_2O$) in 4 parts water. The sulfide solution is added slowly so that the temperature of the acetone solution does not rise above 60°C. After addition is complete, stirring is continued for one-half hour.

References:[10]

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.

(c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(d) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

(e) Committee of Divisions 2 and 8, NDRC, Report on HBX and Tritonal, OSRD Report No. 5406, 31 July 1945.

(f) W. R. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Tech Div Lecture, 9 April 1948.

(g) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition, NDRC Contract W672-ORD-5723.

(h) Eastern Laboratory du Pont, Investigation of Cavity Effect, Final Report, E Lab du Pont, Contract W-672-ORD-5723, 18 September 1943.

(i) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Different Temperatures, PATR No. 2383, November, 1956.

[10] See footnote 1, page 10.

(j) W. S. Cramer, Bulk Compressibility Data on Several High Explosives, NAVORD Report No. 4380, 15 September 1956.

(k) Also see the following Picatinny Arsenal Technical Reports on RDX Composition B:

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1360 | 1211 | 1402 | 1313 | 1224 | 1325 | 1466 | 1207 | 1338 | 1339 |
| 1530 | 1451 | 1482 | 1433 | 1424 | 1435 | 1476 | 1437 | 1388 | 1379 |
| 2100 | 2131 | 1592 | 1803 | 1944 | 1585 | 1556 | 1457 | 1438 | 1469 |
| 2160 | 2151 | | 1983 | 2004 | 1595 | 1756 | 1737 | 1458 | 1819 |
| 2190 | | | 2053 | 2104 | 1865 | 1956 | 1797 | 1688 | 2019 |
| | | | 2063 | | 1885 | 2236 | 2007 | 1728 | |
| | | | 2103 | | 2055 | | 2147 | 1828 | |
| | | | 2233 | | 2125 | | | 1838 | |
| | | | | | 2155 | | | 1978 | |
| | | | | | 2175 | | | 2008 | |
| | | | | | 2235 | | | 2138 | |
| | | | | | | | | 2168 | |

(l) C. Lenchitz, W. Beach and R. Valicky, Enthalpy Changes, Heat of Fusion and Specific Heat of Basic Explosives, PATR No. 2504, January 1959.

| **Composition:** | I* | II** |
|---|---|---|
| % | | |
| RDX | 60 | 55.2 |
| TNT | 40 | 40.0 |
| Wax, added, (Stanolind or Aristowax, 165°/170°F) | 5 | |
| Vinylseal (MA28-14), added | 2 | |
| Vistanex (B120) | | 1.2 |
| Albacer Wax | | 3.6 |
| C/H Ratio | | |

| **Impact Sensitivity, 2 Kg Wt:** | I* | II** |
|---|---|---|
| Bureau of Mines Apparatus, cm | 95 | |
| Sample Wt 20 mg | | |
| Picatinny Arsenal Apparatus, in. | 14 | 13 |
| Sample Wt, mg | 17 | 16 |

| **Friction Pendulum Test:** | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | Unaffected |

| **Rifle Bullet Impact Test:** | Trials % | I* | II** |
|---|---|---|---|
| Explosions | | 0 | 0 |
| Partials | | 0 | 0 |
| Burned | | 5 | 0 |
| Unaffected | | 95 | 100 |

| **Explosion Temperature:** °C | | I* | II** |
|---|---|---|---|
| Seconds, 0.1 (no cap used) | | | |
| 1 | | | |
| 5 | Decomposes | 260 | 270 |
| 10 | | | |
| 15 | | | |
| 20 | | | |

| **75°C International Heat Test:** |
|---|
| % Loss in 48 Hrs |

| **100°C Heat Test:** | I* | II** |
|---|---|---|
| % Loss, 1st 48 Hrs | 0.05 | 0.12 |
| % Loss, 2nd 48 Hrs | 0.19 | 0.18 |
| Explosion in 100 Hrs | None | None |

| **Flammability Index:** |
|---|

| **Hygroscopicity:** % | | |
|---|---|---|
| 30°C, 90% RH | 0.00 | 0.00 |

| **Volatility:** | Nil | Nil |
|---|---|---|

| **Molecular Weight:** | I* | II** |
|---|---|---|
| | See Cyclonite | See Comp B |

| **Oxygen Balance:** | | |
|---|---|---|
| $CO_2$ % | See Cyclonite | See Comp B |
| CO % | See Cyclonite | See Comp B |

| **Density:** gm/cc | | | |
|---|---|---|---|
| | Cast | 1.65 | 1.65 |

| **Melting Point:** °C |
|---|

| **Freezing Point:** °C |
|---|

| **Boiling Point:** °C |
|---|

| **Refractive Index,** | |
|---|---|
| $n_{20}^{D}$ | |
| $n_{25}^{D}$ | |
| $n_{30}^{D}$ | |

| **Vacuum Stability Test:** | I* | II** |
|---|---|---|
| cc/40 Hrs, at | | |
| 90°C | | |
| 100°C | | |
| 120°C | 0.99 | 0.92 |
| 135°C | | |
| 150°C | 11+ | 11+ |

| **200 Gram Bomb Sand Test:** | I* | II** |
|---|---|---|
| Sand, gm | 52.7 | 55.0 |

| **Sensitivity to Initiation:** | I* | II** |
|---|---|---|
| Minimum Detonating Charge, gm | | |
| Mercury Fulminate | | |
| Lead Azide | 0.22 | 0.26 |
| Tetryl | | |

| **Ballistic Mortar, % TNT:** |
|---|

| **Trauzl Test, % TNT:** |
|---|

| **Plate Dent Test:** |
|---|
| Method |
| Condition |
| Confined |
| Density, gm/cc |
| Brisance, % TNT |

| **Detonation Rate:** |
|---|
| Confinement |
| Condition |
| Charge Diameter, in. |
| Density, gm/cc |
| Rate, meters/second |

*Desensitized Comp B, designated I, uses emulsified wax.
**Desensitized Comp B, designated II, uses coated RDX.

# Composition B, Desensitized

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**

| | I* | II** |
|---|---|---|
| Density, gm/cc | 1.65 | 1.65 |
| Charge Wt, lb | 0.87 | 0.86 |
| **Total No. of Fragments:** | | |
| For TNT | 514 | 514 |
| For Subject HE | 609 | 659 |

**Fragment Velocity:** ft/sec

At 9 ft

At 25½ ft

Density, gm/cc

**Blast (Relative to TNT):**

**Air:**

Peak Pressure

Impulse

Energy

**Air, Confined:**

Impulse

**Under Water:**

Peak Pressure

Impulse

Energy

**Underground:**

Peak Pressure

Impulse

Energy

*Desensitized Comp B, designated I, uses emulsified wax.

**Desensitized Comp B, designated II, uses coated RDX.

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Yellow-brown

**Principal Uses:** Bombs

**Method of Loading:** Cast

**Loading Density:** gm/cc 1.65

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | |

| Viscosity, poises: | I* | II** |
|---|---|---|
| Temp, 83°C | 3.5 | 3.1 |
| 95°C | 2.6 | 2.7 |

References:

(a) See the following Picatinny Arsenal Technical Reports on RDX Composition B, Desensitized:

| 1 | 3 | 5 | 6 |
|---|---|---|---|
| 2151 | 1313 | 1435 | 1756 |
| | 2053 | 1865 | |

# Composition C

**Composition:**
%

| | |
|---|---|
| RDX | 88.3 |
| Plasticizer, non-explosive | 11.7* |

*Nonexplosive oily plasticizer containing 0.6% lecithin.

C/H Ratio

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 100+ |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | |
| Sample Wt, mg | |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | |
| Fiber Shoe | |

**Rifle Bullet Impact Test:** Trials

| | % |
|---|---|
| Explosions | 0 |
| Partials | 0 |
| Burned | 0 |
| Unaffected | 100 |

**Explosion Temperature:** °C

Seconds, 0.1 (no cap used)

| | | |
|---|---|---|
| 1 | | |
| 5 | Decomposes | 285 |
| 10 | | |
| 15 | | |
| 20 | | |

**75°C International Heat Test:**
% Loss in 48 Hrs

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.04 |
| % Loss, 2nd 48 Hrs | 0.00 |
| Explosion in 100 Hrs | None |

**Flammability Index:**

**Hygroscopicity:** % 30°C, 95% RH 0.25

**Volatility:** 25°C, 5 days 0.00

**Molecular Weight:**

**Oxygen Balance:**
$CO_2$ %
CO %

**Density:** gm/cc

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$
$n_{25}^{D}$
$n_{30}^{D}$

**Vacuum Stability Test:**
cc/40 Hrs, at

| | |
|---|---|
| 90°C | |
| 100°C | 0.3 |
| 120°C | 0.7 |
| 135°C | |
| 150°C | |

**200 Gram Bomb Sand Test:**

| | |
|---|---|
| Sand, gm | 46.5 |

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | |
| Lead Azide | 0.25 |
| Tetryl | 0.11 |

**Ballistic Mortar, % TNT:** (a) 120

**Trauzl Test, % TNT:**

**Plate Dent Test:**

| | |
|---|---|
| Method | A |
| Condition | Hand Tamped |
| Confined | Yes |
| Density, gm/cc | 1.58 |
| Brisance, % TNT | 112 |

**Detonation Rate:**

| | |
|---|---|
| Confinement | |
| Condition | |
| Charge Diameter, in. | |
| Density, gm/cc | |
| Rate, meters/second | |

# Composition C

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | (f) Glass Cones | (g) Steel Cones |
|---|---|---|
| Hole Volume | 113 | 114 |
| Hole Depth | 101 | 114 |

**Color:** White

**Principal Uses:** Plastic demolition explosive

**Method of Loading:** Hand tamped

**Loading Density:** gm/cc 1.49

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | Exudes above 40°C |

Plasticity:

| | |
|---|---|
| Below 0°C | Brittle (0°C) |
| 0-40°C | Plastic |
| Above 40°C | Exudes (40°C) |

References:

See references for Composition C-4.

## Composition C-2

**Composition:**

| | % |
|---|---|
| RDX | 78.7 |
| TNT | 5.0 |
| DNT | 12.0 |
| MNT | 2.7 |
| NC | 0.6 |
| Solvent | 1.0 |

C/H Ratio

**Impact Sensitivity, 2 Kg Wt:**
Bureau of Mines Apparatus, cm 90
Sample Wt 20 mg
Picatinny Arsenal Apparatus, in.
Sample Wt, mg

**Friction Pendulum Test:**
Steel Shoe
Fiber Shoe

**Rifle Bullet Impact Test:**

| | Trials | % |
|---|---|---|
| Explosions | | 0 |
| Partials | | 20 |
| Burned | | 0 |
| Unaffected | | 80 |

**Explosion Temperature:** °C
Seconds, 0.1 (no cap used)
1
5 Decomposes 285
10
15
20

**75°C International Heat Test:**
% Loss in 48 Hrs

**100°C Heat Test:**
% Loss, 1st 48 Hrs 1.8
% Loss, 2nd 48 Hrs 1.4
Explosion in 100 Hrs None

**Flammability Index:** 178

**Hygroscopicity:** % 30°C, 95% RH 0.55

**Volatility:** 25°C, 5 days 0.00

**Molecular Weight:**

**Oxygen Balance:**
$CO_2$ %
CO %

**Density:** gm/cc

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$
$n_{25}^{D}$
$n_{30}^{D}$

**Vacuum Stability Test:**
cc/40 Hrs, at
90°C
100°C 2.0
120°C 9.0
135°C
150°C

**200 Gram Bomb Sand Test:**
Sand, gm 47.5

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm
Mercury Fulminate
Lead Azide 0.25
Tetryl 0.10

**Ballistic Mortar, % TNT:** (a) 126

**Trauzl Test, % TNT:**

**Plate Dent Test:** (c)

| | |
|---|---|
| Method | B |
| Condition | Hand tamped |
| Confined | No |
| Density, gm/cc | 1.52 |
| Brisance, % TNT | 111 |

**Detonation Rate:** (d)

| | |
|---|---|
| Confinement | None |
| Condition | Hand tamped |
| Charge Diameter, in. | 1.0 |
| Density, gm/cc | 1.57 |
| Rate, meters/second | 7660 |

## Composition C-2

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** White

**Principal Uses:** Plastic demolition explosive

**Method of Loading:** Hand tamped

**Loading Density:** gm/cc 1.57

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | Volatilizes above 52°C |

Plasticity:

| | |
|---|---|
| Below 0°C | Plastic (-30°C) |
| 0-40°C | Plastic |
| above 40°C | Hard (52°C)* |

*Due to volitalization of plasticizer.

References:

See references for Composition C-4.

## Composition C-3

**Composition:**

| | % |
|---|---|
| RDX | 77 |
| Tetryl | 3 |
| TNT | 4 |
| DNT | 10 |
| MNT | 5 |
| NC | 1 |
| C/H Ratio | |

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 100+ |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 14 |
| Sample Wt, mg | 33 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | Unaffected |

**Rifle Bullet Impact Test:**

| | Trials % |
|---|---|
| Explosions | 0 |
| Partials | 40 |
| Burned | 0 |
| Unaffected | 60 |

**Explosion Temperature:** °C

Seconds, 0.1 (no cap used)

| | | |
|---|---|---|
| 1 | | |
| 5 | Decomposes | 280 |
| 10 | | |
| 15 | | |
| 20 | | |

**75°C International Heat Test:**

% Loss in 48 Hrs

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 3.20 |
| % Loss, 2nd 48 Hrs | 1.63 |
| Explosion in 100 Hrs | None |

**Flammability Index:**

**Hygroscopicity:** % 30°C, 95% RH 2.4

**Volatility:** 25°C, 5 days 1.15

**Molecular Weight:**

**Oxygen Balance:**

$CO_2$ %

CO %

**Density:** gm/cc

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$

$n_{25}^{D}$

$n_{30}^{D}$

**Vacuum Stability Test:**

cc/40 Hrs, at

| | |
|---|---|
| 90°C | |
| 100°C | 1.21 |
| 120°C | 11+ |
| 135°C | |
| 150°C | |

**200 Gram Bomb Sand Test:**

| | |
|---|---|
| Sand, gm | 53.1 |

**Sensitivity to Initiation:**

Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | |
| Lead Azide | 0.20 |
| Tetryl | 0.08 |

**Ballistic Mortar, % TNT:** (a) 126

**Trauzl Test, % TNT:** (b) 117

**Plate Dent Test:** (c)

| | |
|---|---|
| Method | B |
| Condition | Hand tamped |
| Confined | No |
| Density, gm/cc | 1.57 |
| Brisance, % TNT | 118 |

**Detonation Rate:** (d)

| | |
|---|---|
| Confinement | None |
| Condition | Hand tamped |
| Charge Diameter, in. | 1.0 |
| Density, gm/cc | 1.60 |
| Rate, meters/second | 7625 |

## Composition C-3

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

| | |
|---|---|
| Density, gm/cc | 158 |
| Charge Wt, lb | 2045 |

**Total No. of Fragments:**

| | |
|---|---|
| For TNT | 703 |
| For Subject HE | 944 |

**3 inch HE, M42A1 Projectile, Lot KC-5:**

| | |
|---|---|
| Density, gm/cc | 1.60 |
| Charge Wt, lb | 0.842 |

**Total No. of Fragments:**

| | |
|---|---|
| For TNT | 514 |
| For Subject HE | 671 |

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**

| | |
|---|---|
| Peak Pressure | 105 |
| Impulse | 109 |
| Energy | |

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Yellow

**Principal Uses:** Plastic demolition explosive

**Method of Loading:** Hand tamped

**Loading Density:** gm/cc 1.58

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | Exudes at 77°C |

Plasticity:

| | |
|---|---|
| Below 0°C | Hard (-29°C) |
| 0-40°C | Plastic |
| Above 40°C | Exudes (77°C) |

Booster Sensitivity Test: (h)

| | |
|---|---|
| Condition | Pressed |
| Tetryl, gm | 100 |
| Wax, in. for 50% Detonation | 1.36 |
| Density, gm/cc | 1.62 |

References:

See references for Composition C-4.

**Composition:**

| | % |
|---|---|
| RDX | 91 |
| Plasticizer, non-explosive | 9* |

* Contains polyisobutylene 2.1%; motor oil 1.6% and di(2-ethylhexyl) sebacate 5.3%.

C/H Ratio

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 100+ |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 19 |
| Sample Wt, mg | 27 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | Unaffected |

**Rifle Bullet Impact Test:**

| | Trials % |
|---|---|
| Explosions | 0 |
| Partials | 0 |
| Burned | 20 |
| Unaffected | 80 |

**Explosion Temperature:** °C

| Seconds, 0.1 (no cap used) | |
|---|---|
| 1 | |
| 5 | 290 |
| 10 | |
| 15 | |
| 20 | |

**75°C International Heat Test:**
% Loss in 48 Hrs

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.13 |
| % Loss, 2nd 48 Hrs | 0.00 |
| Explosion in 100 Hrs | None |

**Flammability Index:**

**Hygroscopicity:** % 30°C, 95% RH Nil

**Volatility:**

**Molecular Weight:**

**Oxygen Balance:**
$CO_2$ %
CO %

**Density:** gm/cc

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$
$n_{25}^{D}$
$n_{30}^{D}$

**Vacuum Stability Test:**

| cc/40 Hrs, at | |
|---|---|
| 90°C | |
| 100°C | 0.26 |
| 120°C | |
| 135°C | |
| 150°C | |

**200 Gram Bomb Sand Test:**

| | |
|---|---|
| Sand, gm | 55.7 |

**Sensitivity to Initiation:**

| Minimum Detonating Charge, gm | |
|---|---|
| Mercury Fulminate | |
| Lead Azide | 0.20 |
| Tetryl | 0.10 |

**Ballistic Mortar, % TNT:** (a) 130

**Trauzl Test, % TNT:**

**Plate Dent Test:** (c)

| | |
|---|---|
| Method | B |
| Condition | Hand tamped |
| Confined | No |
| Density, gm/cc | 1.60 |
| Brisance, % TNT | 115 |

**Detonation Rate:** (d)

| | |
|---|---|
| Confinement | None |
| Condition | Hand tamped |
| Charge Diameter, in. | 1.0 |
| Density, gm/cc | 1.59 |
| Rate, meters/second | 8040 |

## Composition C-4

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Light brown

**Principal Uses:** Plastic demolition explosive

**Method of Loading:** Hand tamped

**Loading Density:** gm/cc 1.60

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | None at 77°C |

Effect of Temperature on Rate of Detonation: (i)

| | | |
|---|---|---|
| 16 hrs at, °C | -54 | 21 |
| Density, gm/cc | 1.36 | 1.35 |
| Rate, m/sec | 7020 | 7040 |

Plasticity:

| | |
|---|---|
| Below 0°C | Plastic (-57°C) |
| 0-40°C | Plastic |
| Above 40°C | Plastic (77°C) |

Preparation:

In manufacturing Composition C-3, the mixed plasticizing agent is heated in a melting kettle at 100°C. Water-wet RDX is added and heating and stirring are continued until all the water is evaporated. This mixture is then cooled and hand pressed into demolition blocks or special item ammunition.

Composition C-4 is prepared by hand kneading and rolling, or in a Schrader Bowl mixer, RDX of 44 micron size or less with the polyisobutylene-plasticizer previously made up in ether. The thoroughly blended explosive is dried in air at 60°C and loosely packed by hand tamping to its maximum density.

Origin:

Developed by the British during World War II as a plastic explosive which could be hand shaped. It was standardized in the United States during World War II and subsequent development led to mixtures designated C-2, C-3 and C-4.

Destruction by Chemical Decomposition:

Composition C-3 is decomposed by adding it slowly to a solution composed of 1 1/4 parts sodium hydroxide, 11 parts water, and 4 parts 95% alcohol, heated to 50°C. After addition of Composition C-3 is complete, the solution is heated to 80°C and maintained at this temperature for 15 minutes.

References:[11]

(a) Committee of Div 2 and 8, NDRC, Report on HBX and Tritonal, OSRD No. 5406, 31 July 1945.

(b) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.

(c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(d) G. H. Messerly, The Rate of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.

M. D. Hurwitz, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1946.

(e) W. R. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Tech Div Lecture, 9 April 1948.

(f) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition, NDRC Contract W672-ORD-5723.

(g) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Final Report, 18 September 1943, NDRC Contract W-672-ORD-5723.

(h) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

[11] See footnote 1, page 10.

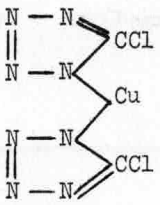
(i) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Temperatures, PATR No. 2383, November 1956.

(j) Also see the following Picatinny Arsenal Technical Reports on RDX Composition C:

| | 0 | 1 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Comp C | 1260 | | 1293 | | | | | 1518<br>1838 | |
| Comp C-2 | | | 1293 | | | 1416 | | 1518 | |
| Comp C-3 | | 1611 | 1713 | 2154 | 1595<br>1695<br>1885 | 1416<br>1556<br>1766 | 1797 | 1518<br>2028 | |
| Comp C-4 | | | | | | 1766 | 1907 | 1828<br>1958 | 1819 |

**Composition:**

| | % |
|---|---|
| C | 8.9 |
| N | 41.5 |
| Cl | 26.2 |
| Cu | 23.4 |
| C/H Ratio | |



**Molecular Weight:** ($CuC_2N_8Cl_2$) 271

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -30 |
| CO % | -18 |

**Density:** gm/cc 2.04

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. 1; (1 lb wt) | 3 |
| Sample Wt, mg | 9 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Exploded |
| Fiber Shoe | Exploded |

**Vacuum Stability Test:**

cc/40 Hrs, at
90°C
100°C
120°C
135°C
150°C

**Rifle Bullet Impact Test:** Trials

| | % |
|---|---|
| Explosions | |
| Partials | |
| Burned | |
| Unaffected | |

**200 Gram Bomb Sand Test:** (f)

| | | |
|---|---|---|
| Sand, gm | 27.4 | 25.3 |
| Black powder fuse | | 17.0 |

**Explosion Temperature:** °C

Seconds, 0.1 (no cap used)

| | |
|---|---|
| 1 | |
| 5 | 305 |
| 10 | |
| 15 | |
| 20 | |

**Sensitivity to Initiation:**

Minimum Detonating Charge, gm

| | | |
|---|---|---|
| Mercury Fulminate | | |
| Lead Azide | 0.20 | 0.30 |
| Tetryl | 0.10 | |

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**75°C International Heat Test:**
% Loss in 48 Hrs

**Plate Dent Test:**
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 2.67 |
| % Loss, 2nd 48 Hrs | 0.10 |
| Explosion in 100 Hrs | None |

**Detonation Rate:**
Confinement
Condition
Charge Diameter, in.
Density, gm/cc
Rate, meters/second

**Flammability Index:**

**Hygroscopicity:** % 30°C, 90% RH 3.11

**Volatility:**

# Copper Chlorotetrazole

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**Fragment Velocity:** ft/sec

At 9 ft

At 25½ ft

Density, gm/cc

**Blast (Relative to TNT):**

**Air:**

Peak Pressure

Impulse

Energy

**Air, Confined:**

Impulse

**Under Water:**

Peak Pressure

Impulse

Energy

**Underground:**

Peak Pressure

Impulse

Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Blue

**Principal Uses:** Primary explosive

**Method of Loading:** Pressed

**Loading Density:** gm/cc (c)

| psi x $10^3$ | 10 | 20 | 40 | 70 |
|---|---|---|---|---|
| | 1.49 | 1.63 | 1.74 | 1.86 |

**Storage:**

| | |
|---|---|
| Method | Wet |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group M |
| Exudation | None |

Stab Sensitivity: (c)

| Density gm/cc | Firing Point (inch-ounces) 0% | 50% | 100% |
|---|---|---|---|
| 1.49 | 9 | 11 | 15 |
| 1.63 | 8.5 | 10 | 12 |
| 1.74 | 6 | 7 | 9 |
| 1.86 | 4 | 5 | 6 |

Heat of:

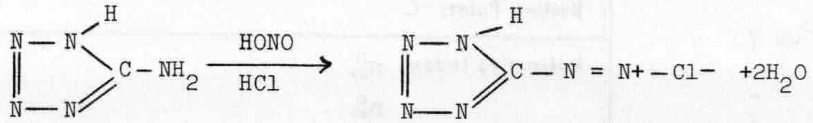
| | |
|---|---|
| Explosion, cal/gm | 432 |

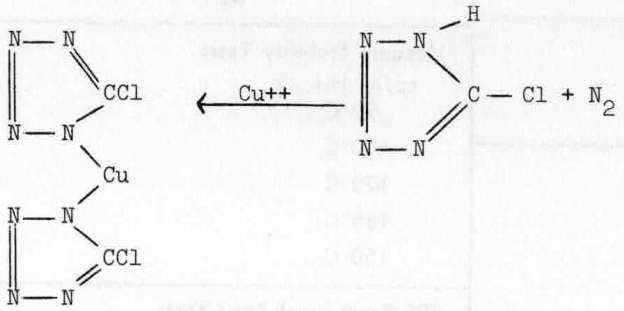
Specific Heat, cal/gm/°C

| | |
|---|---|
| Temp range 0°-30°C | 0.155 |
| Wt of sample, gm | 0.8910 |

Preparation: (a)

Five grams of 5-aminotetrazole are dissolved in a mixture of 200 ml of water and 70 ml of concentrated HCl. Enough kerosene or nujol (which gives a slightly cleaner product) is added to provide a layer of oil approximately 1/4" thick on the surface. With only moderate stirring and external cooling to 10°-15°C, a solution of 5 grams of sodium nitrite in 70 cc of water is added rapidly by means of a burette extending below the oil layer. Immediately after this addition, a solution of 5 gms of cupric chloride in a minimum amount of water is added all at once, and stirring is continued for about 1 hour. The reaction mixture is allowed to stand for a few minutes till the bright blue copper salt separates. The oil is removed by decantation and may be reused. The salt is filtered; washed with water, alcohol, and ether; and dried - giving a yield of 6 grams or 74%.




Origin:

The copper salt of 5-chlorotetrazole was first described in 1929 by R. Stollé (with E. Schick, F. Henke-Stark and L. Krauss) who prepared the compound by reaction of the diazonium chloride of 5-aminotetrazole with copper chloride (Ber 62A, 1123).

References:[12]

(a) R. J. Gaughran and J. V. R. Kaufman, Synthesis and Properties of Halotetrazole Salts, PATR No. 2136, February 1955.

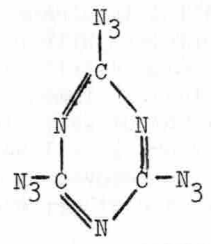
(b) A. M. Anzalone, J. E. Abel and A. C. Forsyth, Characteristics of Explosive Substances for Application in Ammunition, PATR No. 2179, May 1955.

(c) A. C. Forsyth, Pfc, S. Krasner and R. J. Gaughran, Development of Optimum Explosive Trains. An Investigation Concerning Stab Sensitivity versus Loading Density of Some Initiating Compounds, PATR No. 2146, February 1955.

[12]See footnote 1, page 10.

# Cyanuric Triazide

**Composition:**
%
C 17.6
N 82.4



C/H Ratio

**Molecular Weight:** $(C_3N_{12})$ 204

**Oxygen Balance:**
$CO_2$ % -47.1
CO % -23.5

**Density:** gm/cc Crystal 1.54

**Melting Point:** °C 94

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$
$n_{25}^{D}$
$n_{30}^{D}$

**Impact Sensitivity, 2 Kg Wt:**
Bureau of Mines Apparatus, cm 1 kg wt 7
Sample Wt 20 mg
Picatinny Arsenal Apparatus, in. -
Sample Wt, mg -

**Friction Pendulum Test:**
Steel Shoe
Fiber Shoe

**Vacuum Stability Test:**
cc/40 Hrs, at
90°C
100°C
120°C
135°C
150°C

**Rifle Bullet Impact Test:** Trials
%
Explosions
Partials
Burned
Unaffected

**200 Gram Bomb Sand Test:**
Sand, gm 32.2

**Explosion Temperature:** °C
Seconds, 0.1 (no cap used) 252
1
5
10
15
20

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm
Mercury Fulminate -
Lead Azide 0.20
Tetryl 0.10

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**75°C International Heat Test:**
% Loss in 48 Hrs

**Plate Dent Test:**
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**100°C Heat Test:**
% Loss, 1st 48 Hrs
% Loss, 2nd 48 Hrs
Explosion in 100 Hrs

**Detonation Rate:**
Confinement -
Condition -
Charge Diameter, in. 0.3
Density, gm/cc 1.15
Rate, meters/second 5550-5600

**Flammability Index:**

**Hygroscopicity:** %

**Volatility:** Decomposes above 100°C

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Colorless

**Principal Uses:** Not used because of difficulty in controlling sensitivity.

**Method of Loading:** Pressed

**Loading Density:** gm/cc

| | |
|---|---|
| At 200 atmospheres | 1.4 |
| At 800 atmospheres | 1.5 |

**Storage:**

Method

Hazard Class (Quantity-Distance) Class 9

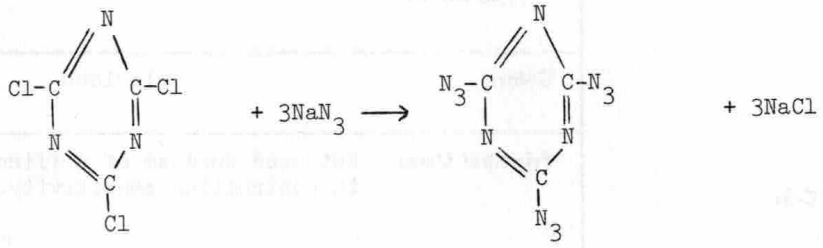
Compatibility Group

Exudation None

# Cyanuric Triazide

Preparation:

By the reaction of cyanuric chloride with an aqueous solution of sodium azide:




Recrystallization should be avoided as it leads to very large crystals which explode when broken.

Origin:

Cyanuric Triazide was prepared in 1847 by Cahours from chlorine and methyl cyanate. Later James improved the process (JCS 51, 268 (1887) and in 1921 E. Ott patented the preparation from cyanuric chloride and sodium azide (Ref b) Taylor and Rinkenbach prepared cyanuric triazide in a pure state and determined its properties (Ref c).

Initiating Efficiency:

Reported to be more efficient than lead azide. Capable of initiating Explosive D.

Solubility:

Insoluble in water; readily soluble in hot ethanol, acetone, benzene, and ether.

Heat of:

| | |
|---|---|
| Formation, cal/gm | -1090 to -1138 |

References:[13]

(a) A. H. Blatt, Compilation of Data on Organic Explosives, OSRD Report No. 2014, 29 February 1944.

(b) Ott and Ohse, Ber 54, 179 (1921).

(c) Taylor and Rinkenbach, Bureau of Mines, RI 2513 (1923).

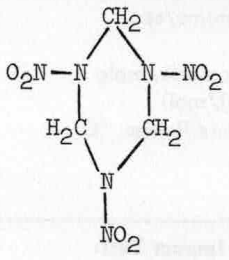
Taylor and Rinkenbach, J Frank Inst 204, 369 (1927).

[13]See footnote 1, page 10.

**Composition:**

| | % |
|---|---|
| C | 16.3 |
| H | 2.7 |
| N | 37.8 |
| O | 43.2 |

C/H Ratio 0.095



**Molecular Weight:** ($C_3H_6N_6O_6$) 222

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -22 |
| CO % | 0.0 |

**Density:** gm/cc Crystal 1.82

**Melting Point:** °C 204

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 32 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 8 |
| Sample Wt, mg | 18 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Explodes |
| Fiber Shoe | Unaffected |

**Vacuum Stability Test:**

| cc/40 Hrs, at | |
|---|---|
| 90°C | |
| 100°C | 0.7 |
| 120°C | 0.9 |
| 135°C | - |
| 150°C | 2.5 |

**Rifle Bullet Impact Test:**

| | Trials % |
|---|---|
| Explosions | 100 |
| Partials | 0 |
| Burned | 0 |
| Unaffected | 0 |

**200 Gram Bomb Sand Test:**

Sand, gm 60.2

**Explosion Temperature:**

| Seconds, 0.1 (no cap used) | °C 405 |
|---|---|
| 1 | 316 |
| 5 Decomposes | 260 |
| 10 | 240 |
| 15 | 235 |
| 20 | - |

**Sensitivity to Initiation:**

Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | 0.19* |
| Lead Azide | 0.05* |
| Tetryl | - |

* Alternative initiating charges.

**75°C International Heat Test:**

% Loss in 48 Hrs 0.03

**Ballistic Mortar, % TNT:** (a) 150

**Trauzl Test, % TNT:** (b) 157

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.04 |
| % Loss, 2nd 48 Hrs | 0.00 |
| Explosion in 100 Hrs | None |

**Plate Dent Test:** (c)

| | |
|---|---|
| Method | A |
| Condition | Pressed |
| Confined | Yes |
| Density, gm/cc | 1.50 |
| Brisance, % TNT | 135 |

**Flammability Index:** (d) 278

**Detonation Rate:**

| | |
|---|---|
| Confinement | None |
| Condition | Pressed |
| Charge Diameter, in. | 1.0 |
| Density, gm/cc | 1.65 |
| Rate, meters/second | 8180 |

**Hygroscopicity:** % 25°C, 100% RH 0.02

**Volatility:** Nil

*Name given by Clarence J. Bain of Picatinny Arsenal. Germans call it Hexogen; Italians call it T4; British, RDX.

**Booster Sensitivity Test:**
Condition
Tetryl, gm
Wax, in. for 50% Detonation
Wax, gm
Density, gm/cc

**Heat of:**

| | |
|---|---|
| Combustion, cal/gm | 2285 |
| Explosion, cal/gm | 1280 |
| Gas Volume, cc/gm | 908 |
| Formation, cal/gm | -96 |
| Solution, cal/mol (28-55% $HNO_3$) | 7.169* |

*Assuming cyclonite unimolecular

**Specific Heat:** cal/gm/°C

| °C | | °C | |
|---|---|---|---|
| 20 | 0.298 | 100 | 0.406 |
| 40 | 0.331 | 120 | 0.427 |
| 60 | 0.360 | 140 | 0.446 |
| 80 | 0.384 | | |

**Burning Rate:**
cm/sec

**Thermal Conductivity:** (h)

| | | |
|---|---|---|
| cal/sec/cm/°C | 1.263 | $6.91 \times 10^{-4}$ |
| Density, gm/cc | 1.533 | $6.98 \times 10^{-4}$ |

**Coefficient of Expansion:**
Linear, %/°C
Volume, %/°C

**Hardness, Mohs' Scale:** 2.5

**Young's Modulus:**
E', dynes/cm²
E, lb/inch²
Density, gm/cc

**Compressive Strength:** lb/inch²

**Vapor Pressure:**
°C mm Mercury

**Decomposition Equation:** (i) $10^{18.5}$

| | |
|---|---|
| Oxygen, atoms/sec (Z/sec) | |
| Heat, kilocalorie/mole (ΔH, kcal/mol) | 47.5 |
| Temperature Range, °C | 213-299 |
| Phase | Liquid |

**Armor Plate Impact Test:**

**60 mm Mortar Projectile:**
50% Inert, Velocity, ft/sec
Aluminum Fineness

**500-lb General Purpose Bombs:**

Plate Thickness, inches

1
1¼
1½
1¾

**Bomb Drop Test:**

**T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:**

Max Safe Drop, ft

**500-lb General Purpose Bomb vs Concrete:**

Height, ft
Trials
Unaffected
Low Order
High Order

**1000-lb General Purpose Bomb vs Concrete:**

Height, ft
Trials
Unaffected
Low Order
High Order

# Cyclonite (RDX)

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** White

**Principal Uses:** Detonator base charge, and ingredient for projectile and bomb fillers

**Method of Loading:** Pressed

**Loading Density:** gm/cc

| psi x $10^3$ | 3 | 5 | 10 | 12 | 15 | 20 |
|---|---|---|---|---|---|---|
| | 1.46 | 1.52 | 1.60 | 1.63 | 1.65 | 1.68 |

**Storage:**

| | |
|---|---|
| Method | Wet |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group M (wet)<br>Group L (dry) |
| Exudation | None |

Effect of Temperature on Rate of Detonation:

| | | (k) |
|---|---|---|
| 16 hrs at, °C | -54 | 21 |
| Density, gm/cc | 1.61 | 1.62 |
| Rate, m/sec | 8100 | 8050 |

Effect of Temperature on Impact Sensitivity:

| Temp. °C | PA Impact Test 2Kg Wt, inches |
|---|---|
| Room | 9 |
| 32.2 | 8 |
| 104 | 5 |

# Cyclonite (RDX)

Solubility of Cyclonite; gm/100 gm of the following substances: (j)

**Water**

| °C | % |
|---|---|
| 30 | 0.005 |
| 50 | 0.025 |
| 70 | 0.076 |
| 90 | 0.19 |
| 100 | 0.28 |

**Alcohol**

| °C | % |
|---|---|
| 0 | 0.040 |
| 20 | 0.105 |
| 40 | 0.240 |
| 60 | 0.579 |
| 78 | 1.195 |

**Acetone**

| °C | % |
|---|---|
| 0 | 4.4 |
| 20 | 7.3 |
| 40 | 11.5 |
| 60 | 18. |

**Benzene**

| °C | % |
|---|---|
| 20 | 0.05 |
| 40 | 0.09 |
| 60 | 0.20 |
| 80 | 0.41 |

**Toluene**

| °C | % |
|---|---|
| 0 | 0.015 |
| 20 | 0.02 |
| 40 | 0.05 |
| 60 | 0.13 |
| 80 | 0.30 |
| 100 | 0.65 |

**Ethyl acetate**

| °C | % |
|---|---|
| 28 | 2.9 |
| 94 | 18. |

**Carbon tetrachloride**

| °C | % |
|---|---|
| 50 | 0.005 |
| 60 | 0.007 |
| 70 | 0.009 |

**Methanol**

| °C | % |
|---|---|
| 0 | 0.14 |
| 20 | 0.23 |
| 40 | 0.47 |
| 60 | 1.1 |

**Ether**

| °C | % |
|---|---|
| 10 | 0.05 |
| 20 | 0.056 |
| 30 | 0.076 |

**TNT**

| °C | % |
|---|---|
| 80 | 4.4 |
| 85 | 5.0 |
| 90 | 5.55 |
| 95 | 6.2 |
| 100 | 7.0 |
| 105 | 7.9 |

**Isoamyl alcohol**

| °C | % |
|---|---|
| 0 | 0.02 |
| 20 | 0.03 |
| 40 | 0.065 |
| 60 | 0.22 |
| 80 | 0.54 |
| 100 | 1.35 |

**Methyl acetate**

| °C | % |
|---|---|
| 20 | 2.9 |
| 30 | 3.3 |
| 40 | 4.1 |
| 50 | 5.6 |

**β-Ethoxyethyl acetate**

| °C | % |
|---|---|
| 20 | 0.15 |
| 30 | 0.16 |
| 40 | 0.19 |
| 50 | 0.25 |

**Chlorobenzene**

| °C | % |
|---|---|
| 20 | 0.33 |
| 30 | 0.44 |
| 40 | 0.56 |
| 50 | 0.74 |

**Trichloroethylene**

| °C | % |
|---|---|
| 20 | 0.20 |
| 30 | 0.22 |
| 40 | 0.24 |
| 50 | 0.26 |

**Tetrachloroethane**

| °C | % |
|---|---|
| 38 | 0.09 |

**Isopropanol**

| °C | % |
|---|---|
| 38 | 0.18 |

**Isobutanol**

| °C | % |
|---|---|
| 20 | 0.0 |

**Chloroform**

| °C | % |
|---|---|
| 20 | 0.01 |

**Mesityloxide**

| °C | % |
|---|---|
| 27 | 3.2 |
| 97 | 12.2 |

**Cyclohexanone**

| °C | % |
|---|---|
| 25 | 12.7 |
| 97 | 25 |

**Nitrobenzene**

| °C | % |
|---|---|
| 25 | 1.5 |
| 97 | 12.4 |

**Nitroethane**

| °C | % |
|---|---|
| 28 | 3.6 |
| 93 | 19 |

**Cyclopentanone**

| °C | % |
|---|---|
| 28 | 11.5 |
| 90 | 37 |

**Acetonitrile**

| °C | % |
|---|---|
| 28 | 11 |
| 82 | 33 |

**Methyl ethyl ketone**

| °C | % |
|---|---|
| 28 | 5.6 |
| 95 | 14 |

Solubility of Cyclonite, Holston Lot E-2-5 in Various Solvents:

| Solvent | Boiling Point, °C | Grade or Source* | Solubility gm/100 gm Solvent 28°C | Heated | Crystalline Form |
|---|---|---|---|---|---|
| Acetone | 56 | CP | 8.2 | 16.5 at 60°C | hexagonal-thick |
| Cyclohexanone | 155.6 | CP | 13.0 | 24.0 at 93°C | cubic (massive form) |
| Nitromethane | 100.8 | | 1.5 | 12.4 at 97°C | plates |
| Acetonitrile | 81.6 | Miacet Chem. Co. | 11.3 | 33.4 at 93°C | plates |
| 1-Nitropropane | 126.5 | EK Pract | 1.4 | 10.6 at 93°C | short needles |
| 2-Nitropropane | 120 | EK Pract | 2.3 | 11.6 at 93°C | short needles |
| 2,4-Pentanedione | 140.5 | Carbide & Carbon | 2.9 | 18.3 at 93°C | flat prisms |
| Methylisobutylketone | 115.8 | | 2.4 | 9.6 at 93°C | long prisms |
| n-Propylacetate | 101.6 | EK Red Label | 1.5 | 6.0 at 93°C | long prisms, some cubic |
| n-Butylformate | 105.6 | EK Red Label | 1.4 | 4.6 at 93°C | long prisms |
| Ethyl acetate | 77.1 | Baker's CP | 2.0 | 6.1 at boil. | hexagonal plates |
| n-Propylpropionate | 121 | EK Red Label | 0.8 | 1.6 at 93°C | short prisms, some cubic |
| Butylacetate | 126.5 | EK Technical | 1.1 | 4.0 at 93°C | long prisms |
| Methylethylketone | 79.6 | | 5.6 | 13.9 at boil. | coarse plates |
| Nitroethane | 114.2 | EK Red Label | 3.6 | 19.5 at 93°C | plates |
| Isopropylacetate | 88-90 | CP | 1.1 | 3.2 at boil. | long prisms |
| Mesityloxide | 128 | EK Red Label | 4.8 | 14.5 at 93°C | plates |
| n-Amylacetate | 146 | CP | 1.0 | 2.1 at 93°C | prisms |
| Dimethylcarbonate | 88-91 | EK Red Label | 1.4 | 6.6 at boil. | plates |
| Diethylcarbonate | 125-126.5 | EK Red Label | 0.7 | 3.2 at 93°C | prisms |
| Isoamylacetate | 132 | CP | 1.2 | 3.6 at 93°C | prisms |
| Ethylpropionate | 98-100 | EK Red Label | 3.0 | 10.7 at 93°C | fairly thick hex plates |
| Methyl-n-butyrate | 101.5-103.5 | EK Red Label | 1.2 | 4.9 at 93°C | needles |
| Cyclopentanone | 130.6 | EK Red Label | 11.5 | 39.0 at 93.5°C | hexagonal plates |
| Acrylonitrile | 77.3 | Cyanamid Co. | 4.0 | 16.4 at boil. | flat plates |
| Methylcellosolveacetate | 144.5 | Carbide & Carbon | 1.6 | 8.8 at 93°C | massive hexagons and prisms |

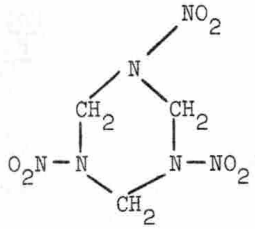
* EK, Eastman Kodak; Pract, practical.

## Cyclonite (RDX)

Preparation:

(Summary Technical Report of the NDRC, Div 8, Vol 1)

$$(CH_2)_6N_4 + 4HNO_3 + 2NH_4NO_3 + 6(CH_3CO)_2O$$



Ammonium nitrate and acetic anhydride are placed in a flask and, while the mixture is stirred at 75°C, the following three liquids are introduced concurrently and proportionately: acetic anhydride, concentrated nitric acid, and a solution of hexamine in glacial acetic acid. The final mixture is held for a short time at 75°C, diluted with water to 30% acetic acid, and simmered to hydrolyze unstable reaction by-products, which are a mixture of various nitrated and acetylated derivatives of hexamine fragments. After simmering, the slurry is cooled and the precipitated cyclonite removed by filtration. The yield is 78% of the theoretical amount (2 moles) of cyclonite melting at 199°C. By dissolving the ammonium nitrate in the nitric acid, a continuous process, based on 3 liquids, is possible.

The product is recrystallized from acetone, or cyclohexanone, to (a) remove acidity, (b) control particle size and (c) to produce stable $\beta$-HMX. The preparative procedure described above, the Bachmann or Combination process, yields cyclonite containing 3-8% HMX.

Origin:

First prepared by Henning in 1899 (German Patent 104,280) and later by von Hertz (U. S. Patent 1, 402,693) in 1922 who recognized its value as an explosive. Not used on a large scale in explosive ammunition until World War II.

Destruction by Chemical Decomposition:

Cyclonite (RDX) is decomposed by adding it slowly to 25 times its weight of boiling 5% sodium hydroxide. Boiling should be continued for one-half hour.

References: [14]

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) Ph. Naoum, Z. ges Schiess Sprengstoffw, pp. 181, 229, 267 (27 June 1932).

(c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(d) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.

[14] See footnote 1, page 10.

(e) Armament Research Department (Woolwich), Solubility of RDX in Nitric Acid (ARD Expl Rpt 322/43 September 1943).

(f) Report AC-2587.

(g) International Critical Tables
Land. Bornst.

B. T. Fedoroff et al, A Manual for Explosives Laboratories, Lefax Society Inc, Philadelphia, 1943-6.

(h) E. Hutchinson, The Thermal Sensitiveness of Explosives. The Thermal Conductivity of Explosive Materials, AC 2861, First Report, August 1942.

(i) R. J. Finkelstein and G. Gamow, Theory of the Detonation Process, NAVORD Report No. 90-46, 20 April 1947.

(j) International Critical Tables.

(k) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Different Temperatures, PATR No. 2383, November 1956.

(l) Also see the following Picatinny Arsenal Technical Reports on Cyclonite:

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1170 | 1211 | 582 | 863 | 1184 | 65 | 1236 | 857 | 1438 | 709 |
| 1290 | 1241 | 1342 | 1193 | 1414 | 1175 | 1316 | 1207 | 1458 | 1379 |
| 1360 | 1311 | 1352 | 1293 | 1454 | 1185 | 1416 | 1427 | 1498 | 1429 |
| 1450 | 1421 | 1372 | 1433 | 1614 | 1435 | 1446 | 1437 | 1578 | 1449 |
| 1760 | 1481 | 1402 | 1483 | 1634 | 1445 | 1466 | 1517 | 1838 | 1469 |
| 1980 | 1561 | 1452 | 1503 | 2024 | 1715 | 1476 | 1617 | 1958 | 1709 |
| 2100 | 1611 | 1492 | 1693 | 2154 | 1855 | 1516 | 1687 | 1958 | 1909 |
| | 1651 | 1532 | 1713 | 2204 | 1885 | 1556 | 1737 | 2008 | 2059 |
| | 1741 | 2062 | 1793 | | 1915 | 1756 | 1747 | 2028 | 2179 |
| | 1751 | 2112 | 1923 | | 1935 | 1766 | 1787 | 2178 | |
| | 1761 | | | | 2095 | 1796 | 1797 | 2198 | |
| | 2131 | | | | 2125 | 1836 | 1957 | | |
| | 2151 | | | | 2205 | 1936 | 2147 | | |
| | | | | | | 1956 | 2227 | | |
| | | | | | | 2016 | | | |
| | | | | | | 2056 | | | |
| | | | | | | 2176 | | | |

# Cyclotol, 75/25

**Composition:**

| | % |
|---|---|
| RDX | 75 |
| TNT | 25 |

C/H Ratio

**Impact Sensitivity, 2 Kg Wt:**
Bureau of Mines Apparatus, cm
Sample Wt 20 mg
Picatinny Arsenal Apparatus, in.
Sample Wt, mg

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | Unaffected |

**Rifle Bullet Impact Test:** Trials

| | | % |
|---|---|---|
| Explosions | | 30 |
| Partials | Smokes | 40 |
| Burned | | 0 |
| Unaffected | | 30 |

**Explosion Temperature:** °C
Seconds, 0.1 (no cap used)
1
5
10
15
20

**75°C International Heat Test:**
% Loss in 48 Hrs

**100°C Heat Test:**
% Loss, 1st 48 Hrs
% Loss, 2nd 48 Hrs
Explosion in 100 Hrs

**Flammability Index:**

**Hygroscopicity:** %

**Volatility:**

**Molecular Weight:** 224

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -35 |
| CO % | - 6 |

**Density:** gm/cc Cast 1.71

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$
$n_{25}^{D}$
$n_{30}^{D}$

**Vacuum Stability Test:**
cc/40 Hrs, at

| | |
|---|---|
| 90°C | |
| 100°C | 0.23 |
| 120°C | 0.41 |
| 135°C | - |
| 150°C | - |

**200 Gram Bomb Sand Test:**
Sand, gm

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm
Mercury Fulminate
Lead Azide
Tetryl

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**Plate Dent Test:**
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**Detonation Rate:**

| | | |
|---|---|---|
| Confinement | None | None |
| Condition | Cast | Cast |
| Charge Diameter, in. | 1.0 | 1.0 |
| Density, gm/cc | 1.70 | 1.71 |
| Rate, meters/second | 8035 | 7938 |

**Booster Sensitivity Test:**
Condition
Tetryl, gm
Wax, in. for 50% Detonation
Wax, gm
Density, gm/cc

**Heat of:**

| | | |
|---|---|---|
| Combustion, cal/gm | | 2625* |
| Explosion, cal/gm | | 1225* |
| Gas Volume, cc/gm | | 862 |
| Formation, cal/gm | | |
| Fusion, cal/gm | (h) | 5.0 |

*Calculated from composition of mixture.

**Specific Heat:** cal/gm/°C (h)

| °C | | °C | |
|---|---|---|---|
| -75 | 0.220 | 75 | 0.352 |
| 0 | 0.225 | 85 | 0.325 |
| 25 | 0.254 | 90 | 0.332 |
| 50 | 0.296 | 100 | 0.351 |

**Burning Rate:**
cm/sec

**Thermal Conductivity:**
cal/sec/cm/°C

**Coefficient of Expansion:**
Linear, %/°C

Volume, %/°C

**Hardness, Mohs' Scale:**

**Young's Modulus:**
E', dynes/cm²
E, lb/inch²
Density, gm/cc

**Compressive Strength:** lb/inch²

**Vapor Pressure:**
°C mm Mercury

**Decomposition Equation:**
Oxygen, atoms/sec (Z/sec)
Heat, kilocalorie/mole (ΔH, kcal/mol)
Temperature Range, °C
Phase

**Armor Plate Impact Test:**

**60 mm Mortar Projectile:**
50% Inert, Velocity, ft/sec
Aluminum Fineness

**500-lb General Purpose Bombs:**

Plate Thickness, inches

1
1¼
1½
1¾

**Bomb Drop Test:**

**T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:**

Max Safe Drop, ft

**500-lb General Purpose Bomb vs Concrete:**

Height, ft
Trials
Unaffected
Low Order
High Order

**1000-lb General Purpose Bomb vs Concrete:**

Height, ft
Trials
Unaffected
Low Order
High Order

# Cyclotol, 75/25

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

| | |
|---|---|
| Density, gm/cc | 1.72 |
| Charge Wt, lb | 2.22 |

**Total No. of Fragments:**

| | |
|---|---|
| For TNT | 703 |
| For Subject HE | 1514 |

**3 inch HE, M42A1 Projectile, Lot KC-5:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**Fragment Velocity:** ft/sec

At 9 ft

At 25½ ft

Density, gm/cc

**Blast (Relative to TNT):** (d)

**Air:**

| | |
|---|---|
| Peak Pressure | 111 |
| Impulse | 126 |
| Energy | -- |

**Air, Confined:**

Impulse

**Under Water:**

Peak Pressure

Impulse

Energy

**Underground:**

Peak Pressure

Impulse

Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Yellow-buff

**Principal Uses:** Shaped charge bomb especially fragmentation; HE projectiles; grenades

**Method of Loading:** Cast

**Loading Density:** gm/cc 1.71

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | |

Preparation: See Composition B

Origin: Developed by the British between World Wars I and II and standardized in the United States early in World War II.

Black Modulus at Room Temperature (25°-30°C):

| | |
|---|---|
| Dynes/cm$^2$ x 10$^{-10}$ | 3.09 |
| Density, gm/cc | 1.74 |

Absolute Viscosity, poises:*

| | |
|---|---|
| Temp, 85°C | 210** |
| 90°C | -- |

Efflux Viscosity, Saybolt Seconds:

| | |
|---|---|
| Temp, 85°C | 9-14 |

* Compositions using Spec Grade Type A, Class A RDX.

** Composition prepared using RDX of optimum particle size.

**Composition:**

| | % |
|---|---|
| RDX | 70 |
| TNT | 30 |

C/H Ratio

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 60 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 14 |
| Sample Wt, mg | 20 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | Unaffected |

**Rifle Bullet Impact Test:**

| | Trials % |
|---|---|
| Explosions | 30 |
| Partials | 30 |
| Burned | 0 |
| Unaffected | 40 |

**Explosion Temperature:**

| Seconds, 0.1 (no cap used) | °C |
|---|---|
| 1 | - |
| 5 Decomposes | 265 |
| 10 | |
| 15 | |
| 20 | |

**75°C International Heat Test:**
% Loss in 48 Hrs

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.07 |
| % Loss, 2nd 48 Hrs | 0.08 |
| Explosion in 100 Hrs | None |

**Flammability Index:**

**Hygroscopicity:** % Nil

**Volatility:** Nil

**Molecular Weight:** 224

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -37 |
| CO % | - 8 |

**Density:** gm/cc Cast 1.71

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Vacuum Stability Test:**

| cc/40 Hrs, at | |
|---|---|
| 90°C | |
| 100°C | |
| 120°C | 0.86 |
| 135°C | |
| 150°C | |

**200 Gram Bomb Sand Test:**

| | |
|---|---|
| Sand, gm | 56.6 |

**Sensitivity to Initiation:**

| Minimum Detonating Charge, gm | |
|---|---|
| Mercury Fulminate | 0.21* |
| Lead Azide | 0.20* |
| Tetryl | |

*Alternative initiating charges.

**Ballistic Mortar, % TNT:** (a) 135

**Trauzl Test, % TNT:**

**Plate Dent Test:** (b)

| | |
|---|---|
| Method | B |
| Condition | Cast |
| Confined | No |
| Density, gm/cc | 1.725 |
| Brisance, % TNT | 136 |

**Detonation Rate:**

| | |
|---|---|
| Confinement | None |
| Condition | Cast |
| Charge Diameter, in. | 1.0 |
| Density, gm/cc | 1.73 |
| Rate, meters/second | 8060 |

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

| | |
|---|---|
| Density, gm/cc | 1.71 |
| Charge Wt, lb | 2.213 |
| **Total No. of Fragments:** | |
| For TNT | 703 |
| For Subject HE | 1165 |

**3 inch HE, M42A1 Projectile, Lot KC-5:**

| | |
|---|---|
| Density, gm/cc | 1.72 |
| Charge Wt, lb | 0.923 |
| **Total No. of Fragments:** | |
| For TNT | 514 |
| For Subject HE | 828 |

**Fragment Velocity:** ft/sec

| | |
|---|---|
| At 9 ft | |
| At 25½ ft | |
| Density, gm/cc | |

**Blast (Relative to TNT):** (d)

| | |
|---|---|
| **Air:** | |
| Peak Pressure | 110 |
| Impulse | 120 |
| Energy | -- |
| **Air, Confined:** | |
| Impulse | |
| **Under Water:** | |
| Peak Pressure | |
| Impulse | |
| Energy | |
| **Underground:** | |
| Peak Pressure | |
| Impulse | |
| Energy | |

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones (e) |
|---|---|---|
| Hole Volume | | |
| Hole Depth | 130 | |

**Color:** Yellow-buff

**Principal Uses:** Shaped charge bombs; especially fragmentation HE projectiles, grenades

**Method of Loading:** Cast

**Loading Density:** gm/cc 1.71

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | |

Preparation: See Composition B

Origin: Developed by the British between World Wars I and II and standardized in the United States early in World War II.

Absolute Viscosity, poises:*

| | |
|---|---|
| Temp, 85°C | -- |
| 90°C | 53.2 |

Efflux Viscosity, Saybolt Seconds:

| | |
|---|---|
| Temp, 85°C | 5 |

Heat of: **

| | |
|---|---|
| Combustion, cal/gm | 2685 |
| Explosion, cal/gm | 1213 |
| Gas Volume, cc/gm | 854 |

* Composition using Spec Grade Type A, Class A RDX.

** Calculated from composition of mixture.

**Composition:**
%
RDX 65
TNT 35

C/H Ratio

**Impact Sensitivity, 2 Kg Wt:**
Bureau of Mines Apparatus, cm
Sample Wt 20 mg
Picatinny Arsenal Apparatus, in.
Sample Wt, mg

**Friction Pendulum Test:**
Steel Shoe Unaffected
Fiber Shoe Unaffected

**Rifle Bullet Impact Test:** Trials
%
Explosions
Partials
Burned
Unaffected

**Explosion Temperature:** °C
Seconds, 0.1 (no cap used)
1
5 Decomposes 270
10
15
20

**75°C International Heat Test:**
% Loss in 48 Hrs

**100°C Heat Test:**
% Loss, 1st 48 Hrs
% Loss, 2nd 48 Hrs
Explosion in 100 Hrs

**Flammability Index:**

**Hygroscopicity:** % Nil

**Volatility:** Nil

**Molecular Weight:** 224

**Oxygen Balance:**
$CO_2$ % -40
CO % - 9

**Density:** gm/cc Cast 1.71

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$
$n_{25}^{D}$
$n_{30}^{D}$

**Vacuum Stability Test:**
cc/40 Hrs, at
90°C
100°C
120°C
135°C
150°C

**200 Gram Bomb Sand Test:**
Sand, gm 55.4

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm
Mercury Fulminate
Lead Azide
Tetryl

**Ballistic Mortar, % TNT:** (a) 134

**Trauzl Test, % TNT:**

**Plate Dent Test:**
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**Detonation Rate:**
Confinement None
Condition Cast
Charge Diameter, in. 1.0
Density, gm/cc 1.72
Rate, meters/second 7975

# Cyclotol, 65/35

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

| | |
|---|---|
| Density, gm/cc | 1.71 |
| Charge Wt, lb | 2.253 |

**Total No. of Fragments:**

| | |
|---|---|
| For TNT | 703 |
| For Subject HE | 1153 |

**3 inch HE, M42A1 Projectile, Lot KC-5:**

| | |
|---|---|
| Density, gm/cc | 1.71 |
| Charge Wt, lb | 0.922 |

**Total No. of Fragments:**

| | |
|---|---|
| For TNT | 514 |
| For Subject HE | 769 |

**Fragment Velocity:** ft/sec

| | |
|---|---|
| At 9 ft | |
| At 25½ ft | |
| Density, gm/cc | |

**Blast (Relative to TNT):**

**Air:**
- Peak Pressure
- Impulse
- Energy

**Air, Confined:**
- Impulse

**Under Water:**
- Peak Pressure
- Impulse
- Energy

**Underground:**
- Peak Pressure
- Impulse
- Energy

Heat of: *

| | |
|---|---|
| Combustion, cal/gm | 2755 |
| Explosion, cal/gm | 1205 |
| Gas Volume, cc/gm | 845 |

* Calculated from composition of mixture.

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones (e) |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | 130 |

**Color:** Yellow-buff

**Principal Uses:** Shaped charge bombs; especially fragmentation HE projectiles, grenades

**Method of Loading:** Cast

**Loading Density:** gm/cc 1.71

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | |

Preparation: See Composition B

Origin: Developed by the British between World Wars I and II and standardized in the United States early in World War II.

Eutectic Temperature, °C: 79

| gm RDX/100 gm TNT | |
|---|---|
| 79°C | 4.16 |
| 95°C | 5.85 |

Absolute Viscosity, poises:*

| | |
|---|---|
| Temp, 85°C | 30.2 |
| 90°C | 26.0 |

* Composition using Spec Grade Type A, Class A RDX.

**Composition:**

| | % |
|---|---|
| RDX | 60 |
| TNT | 40 |
| C/H Ratio | |

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 75 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 14 |
| Sample Wt, mg | 19 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | Unaffected |

**Rifle Bullet Impact Test:** Trials

| | % |
|---|---|
| Explosions | 5 |
| Partials | 55 |
| Burned | 25 |
| Unaffected | 15 |

**Explosion Temperature:** °C

Seconds, 0.1 (no cap used)

| | | |
|---|---|---|
| 1 | | |
| 5 | Decomposes | 280 |
| 10 | | |
| 15 | | |
| 20 | | |

**75°C International Heat Test:**

% Loss in 48 Hrs

**100°C Heat Test:**

% Loss, 1st 48 Hrs

% Loss, 2nd 48 Hrs

Explosion in 100 Hrs

**Flammability Index:**

**Hygroscopicity:** % Nil

**Volatility:** Nil

**Molecular Weight:** 224

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -43 |
| CO % | 10 |

**Density:** gm/cc Cast 1.68

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Vacuum Stability Test:**

cc/40 Hrs, at

| | |
|---|---|
| 90°C | |
| 100°C | |
| 120°C | 0.29 |
| 135°C | |
| 150°C | |

**200 Gram Bomb Sand Test:**

Sand, gm 54.6

**Sensitivity to Initiation:**

Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | 0.22* |
| Lead Azide | 0.20* |
| Tetryl | |

*Alternative initiating charges.

**Ballistic Mortar, % TNT:** (a) 1.33

**Trauzl Test, % TNT:**

**Plate Dent Test:** (b)

| | |
|---|---|
| Method | B |
| Condition | Cast |
| Confined | No |
| Density, gm/cc | 1.72 |
| Brisance, % TNT | 132 |

**Detonation Rate:**

| | |
|---|---|
| Confinement | None |
| Condition | Cast |
| Charge Diameter, in. | 1.0 |
| Density, gm/cc | 1.72 |
| Rate, meters/second | 7900 |

# Cyclotol, 60/40

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

| | |
|---|---|
| Density, gm/cc | 1.65 |
| Charge Wt, lb | 2.187 |
| **Total No. of Fragments:** | |
| For TNT | 703 |
| For Subject HE | 998 |

**3 inch HE, M42A1 Projectile, Lot KC-5:**

| | |
|---|---|
| Density, gm/cc | 1.67 |
| Charge Wt, lb | 0.882 |
| **Total No. of Fragments:** | |
| For TNT | 514 |
| For Subject HE | 701 |

| | |
|---|---|
| **Fragment Velocity:** ft/sec | (c) |
| At 9 ft | 2965 |
| At 25½ ft | 2800 |
| Density, gm/cc | -- |

| | |
|---|---|
| **Blast (Relative to TNT):** | (d) |
| **Air:** | |
| Peak Pressure | 104 |
| Impulse | 116 |
| Energy | -- |
| **Air, Confined:** | |
| Impulse | |
| **Under Water:** | |
| Peak Pressure | |
| Impulse | |
| Energy | |
| **Underground:** | |
| Peak Pressure | |
| Impulse | |
| Energy | |
| Heat of: | * |
| Combustion, cal/gm | 2820 |
| Explosion, cal/gm | 1195 |
| Gas Volume, cc/gm | 845 |
| Compressive Strength: lb/inch$^2$ | |
| 1.70 gm/cc | 2200-3000 |

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones (e) |
|---|---|---|
| Hole Volume | 178 | 162 |
| Hole Depth | 125 | 148 |

**Color:** Yellow-buff

**Principal Uses:** Shaped charge bomb; especially fragmentation HE projectiles, grenades

**Method of Loading:** Cast

**Loading Density:** gm/cc 1.68

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | |

Preparation: See Composition B

Origin: Developed by the British between World Wars I and II and standardized in the United States early in World War II.

Bulk Modulus at Room Temperature (25°-30°C):

| | |
|---|---|
| Dynes/cm$^2$ x $10^{-10}$ | 4.14 |
| Density, gm/cc | 1.72 |

Absolute Viscosity, poises:*

| | |
|---|---|
| Temp, 85°C | 12.3 |
| 90°C | -- |

* Compositions using Spec Grade Type A, Class A RDX.

* Calculated from composition of mixture.

References:[15]

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(c) R. W. Drake, Fragment Velocity and Panel Penetration of Several Explosives in Simulated Shells, OSRD Report No. 5622, 2 January 1946.

(d) V. Philipchuk, Free Air Blast Evaluation of RDX-TNT-Al, RDX-TNT, and TNT-Metal Systems, National Northern Summary Report, NN-P-34, April 1956.

(e) Eastern Laboratory, du Pont, Investigation of Cavity Effect. Section III, Variation of Cavity Effect with Composition, NDRC Contract W-672-ORD-5723.

(f) W. S. Cramer, Bulk Compressibility Data on Several High Explosives, NAVORD Report No. 4380, 15 September 1956.

(g) Also see the following Picatinny Arsenal Technical Reports on Cyclotols:

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1290 | 1651 | 1482 | 1483 | 1824 | 1435 | 1476 | 1427 | 1398 | 1469 |
| 1530 | 1741 | | 1793 | 1834 | 1585 | 1756 | 1507 | 1488 | 1509 |
| | | | 1983 | 1944 | | 1796 | 1747 | 1838 | 1709 |
| | | | | 2004 | | 1876 | | | |

(h) C. Lenchitz, W. Beach and R. Valicky, Enthalpy Changes, Heat of Fusion and Specific Heat of Basic Explosives, PATR No. 2504, January 1959.

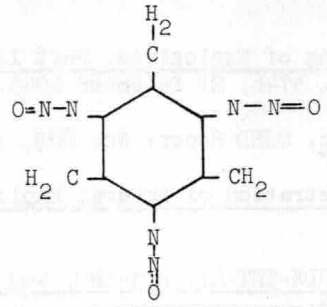
[15]See footnote 1, page 10.

# Cyclotrimethylene Trinitrosamine

**Composition:**

| | % |
|---|---|
| C | 20.6 |
| H | 3.5 |
| N | 48.3 |
| O | 27.6 |

C/H Ratio 0.12



**Molecular Weight:** ($C_3H_6N_6O_3$) 174

**Oxygen Balance:**
- $CO_2$ % -55
- CO % -28

**Density:** gm/cc

**Melting Point:** °C 105 to 107

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Impact Sensitivity, 2 Kg Wt:**
- Bureau of Mines Apparatus, cm
  - Sample Wt 20 mg
- Picatinny Arsenal Apparatus, in. 15 to 22
  - Sample Wt, mg 17 to 20

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | Unaffected |

**Vacuum Stability Test:** (c)

cc/40 Hrs, at

| | | |
|---|---|---|
| 90°C | 0.20 | |
| 100°C | 9.19 | 3.71* |

*Average value of 5 gm sample twice recrystallized from isoamyl alcohol.

**Rifle Bullet Impact Test:**

| | Trials | % |
|---|---|---|
| Explosions | | |
| Partials | | |
| Burned | | |
| Unaffected | | |

**200 Gram Bomb Sand Test:**

| | | |
|---|---|---|
| Sand, gm | 59.2 | 54.1 |

**Explosion Temperature:** °C

Seconds, 0.1 (no cap used)

| | |
|---|---|
| 1 | |
| 5 | 220 |
| 10 | |
| 15 | |
| 20 | |

**Sensitivity to Initiation:**

Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | 0.200** |
| Lead Azide | 0.100** |
| Tetryl | |

**Alternative initiating charges.

**Ballistic Mortar, % TNT:** 130

**Trauzl Test, % TNT:**

**75°C International Heat Test:**
- % Loss in 48 Hrs

**Plate Dent Test:**
- Method
- Condition
- Confined
- Density, gm/cc
- Brisance, % TNT

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 8.79 |
| % Loss, 2nd 48 Hrs | 2.98 |
| Explosion in 100 Hrs | None |

**Detonation Rate:** (b)

| | |
|---|---|
| Confinement | None |
| Condition | Cast |
| Charge Diameter, in. | 1.2 |
| Density, gm/cc | 1.42 |
| Rate, meters/second | 7000 to 7300 |

**Flammability Index:**

**Hygroscopicity:** % 30°C, 90% RH 0.02

**Volatility:**

## Cyclotrimethylene Trinitrosamine

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Yellow

**Principal Uses:** Ingredient of projectile filler

**Method of Loading:** Pressed or cast with added melting point depressants

**Loading Density:** gm/cc — See below

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group M |
| Exudation | None |

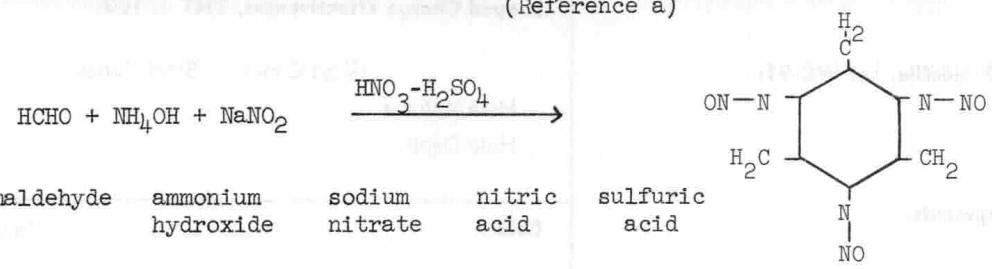
Density at Various Pressures: (b)

| lb/inch$^2$ | gm/cc |
|---|---|
| 2,420 | 1.10 |
| 4,830 | 1.23 |
| 9,650 | 1.37 |
| 14,500 | 1.44 |
| 24,200 | 1.53 |
| 33,800 | 1.57 |
| 42,500 | 1.59 |

Heat of:

| | |
|---|---|
| Combustion, cal/gm | 3158 |
| Explosion, cal/gm | 876 |
| Formation, cal/gm | -914 |

Preparation of Hexahydro-1,3,5-Trinitroso-s-triazine Cyclotrimethylene Trinitrosamine: (Reference a)




An ammoniacal solution of an amine is prepared by adding aqueous formaldehyde to ammonium hydroxide. The rate of addition of formaldehyde is regulated to maintain a solution temperature of 30° to 35°C.

Sodium nitrite is dissolved in water and the solution or slurry is then poured into the previously prepared amine-ammonia solution and totally dissolved by stirring. This solution is chilled to below 0°C.

Into a mixed acid solution, previously prepared by dissolving concentrated nitric acid in water and adding concentrated sulfuric acid, all chilled to -9°C, there is added the cold amine-nitrite solution below the surface of the acid mixture. The addition is regulated to take 20 to 30 minutes.

The resulting foamy head of cyclotrimethylene trinitrosamine is allowed to sit over the icy spent liquor for 1/2 hour and is then collected on a sintered glass funnel and washed to neutrality. The moist cyclotrimethylene trinitrosamine is removed from the funnel and air-dried on filter paper. The dry crude product melts at 106° to 107°C. Recrystallization from isoamyl alcohol gives a pure compound melting at 105° to 107°C.

Origin:

Cyclotrimethylene trinitrosamine was discovered in 1888 simultaneously by Griess and Harrow (Ber 21 (1888), p. 2737) and by Mayer (Ber 21 (1888), p. 2883) when sodium nitrite was allowed to react with hexamethylene tetramine in acid solution. This compound was later studied by Duden and Scharff (Ann 288 (1895), p. 218) and by Delépine who determined its heat of formation, which was negative (Bull Soc chim (3) 15 (1896), p. 1199). Because cyclotrimethylene trinitrosamine could be made at first in very poor yield only, it was a long time before it received consideration for practical application as an explosive. However, the study of cyclotrimethylene trinitrosamine was continued and investigations were made as to its behavior in mixtures with other substances (Prof. D. G. Römer "Report on Explosives," BIOSGP 2-HEC 5742).

Destruction by Chemical Decomposition:

Cyclotrimethylene trinitrosamine is easily decomposed by acid or alkali and even by boiling in water.

High Temperature Decomposition, 0.02 gm in 10 ml Test Tube: (b)

| Immersed 10 minutes in bath heated at 5°/minute | | Temp. °C |
|---|---|---|
| (1) | Melting begins | 105 |
| | Decomposition begins | 150 |
| | Nitrous gas | 160 |
| | Entire decomposition | 170 |
| (2) | Some bubbles | 110 |
| | Very slow decomposition | 150 |
| | Decomposes in 2 minutes | 200 |
| | Decomposes in 40 seconds | 250 |
| | Immediate decomposition | 300 |

Long Term Stability: (b)

Cyclotrimethylene Trinitrosamine loosely packed in covered wooden boxes for six years at ambient temperature and protected from the sun:

1. Explosive showed no color change.
2. Melting point decreased from 104.5° to 104°C.
3. Coefficient of "Utilisation Practique" decreased from 125.5 to 123.5.
4. An Abel Test at 110°C gave no color to iodine starch paper in 15 minutes.

Fusion Tests, Mixtures of Cyclotrimethylene Trinitrosamine and TNT: (b)

| Cyclotrimethylene Trinitrosamine, % | Melting Point, °C |
|---|---|
| 10 | 74 |
| 20 | 68 |
| 30 | 62 |
| 40 | 55 |
| 42 | 55 (Eutectic) |
| 50 | 61 |
| 60 | 69 |
| 70 | 77 |
| 95 | 95 |

Eutectic Composition With TNT: (b)

42% Cyclotrimethylene Trinitrosamine
58% TNT

Rate of Detonation, meters/second

7,000

Reaction of Cyclotrimethylene Trinitrosamine With Other Materials: (b)

| | |
|---|---|
| 1. Iron powder | Slight reaction |
| 2. Copper powder | Slight reaction |
| 3. Aluminum powder | Slight reaction |
| 4. 2 parts picric acid + 1 part R-Salt | a. Violent decomposition after 2 hours at 10°C<br>b. Violent decomposition after 10 to 15 minutes at 100°C |
| 5. 2 parts nitroglycerin + 1 part R-Salt | No evidence of decomposition after 5 days at 90°C |

Detonation Rate: (b)

| Confinement | Paper cartridge |
|---|---|
| Condition | Pressed |
| Charge Diameter, in. | 1.18 |
| Rate, meters/second | Density, gm/cc |
| 5180 | 0.85 |
| 5760 | 1.00 |
| 6600 | 1.20 |
| 7330 | 1.40 |
| 7600 | 1.50 |
| 7800 | 1.57 |

References:[16]

(a) Arthur D. Little, Inc. Progress Report No. 106, Fundamental Development of High Explosives, April 1955, Contract No. DAI-19-020-501-ORD(P)-33.

(b) Louis Médard and Maurice Dutour, "Étude Des Proprietés De La Cyclotriméthyléne Trinitrosamine," Mém poudr, 37, 1924 (1954).

(c) H. A. Bronner and J. V. R. Kaufman, "Synthesis and Properties of R-Salt," PATR in preparation 1959.

(d) Also see the following Picatinny Arsenal Technical Reports on Cyclotrimethylene Trinitrosamine: 1174, 2179.

[16]See footnote 1, page 10.

# DBX (Depth Bomb Explosive)

**Composition:**

| | % |
|---|---|
| Ammonium Nitrate | 21 |
| RDX | 21 |
| TNT | 40 |
| Aluminum | 18 |
| C/H Ratio | |

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 35 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 13 |
| Sample Wt, mg | 14 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | |
| Fiber Shoe | |

**Rifle Bullet Impact Test:**

| | Trials | % |
|---|---|---|
| Explosions | | |
| Partials | | |
| Burned | | |
| Unaffected | | |

**Explosion Temperature:** °C

Seconds, 0.1 (no cap used)

| | | |
|---|---|---|
| 1 | | |
| 5 | Ignites | 400 |
| 10 | | |
| 15 | | |
| 20 | | |

**75°C International Heat Test:**

% Loss in 48 Hrs

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | |
| % Loss, 2nd 48 Hrs | |
| Explosion in 100 Hrs | |

**Flammability Index:**

**Hygroscopicity:** %

**Volatility:**

**Molecular Weight:** 83

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -46 |
| CO % | -26 |

**Density:** gm/cc Cast 1.68

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Vacuum Stability Test:**

cc/40 Hrs, at

| | |
|---|---|
| 90°C | |
| 100°C | |
| 120°C | 6.15 |
| 135°C | |
| 150°C | |

**200 Gram Bomb Sand Test:**

Sand, gm 58.5

**Sensitivity to Initiation:**

Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | |
| Lead Azide | 0.20 |
| Tetryl | 0.10 |

**Ballistic Mortar, % TNT:** (a) 146

**Trauzl Test, % TNT:**

**Plate Dent Test:** (b)

| | |
|---|---|
| Method | B |
| Condition | Cast |
| Confined | No |
| Density, gm/cc | 1.76 |
| Brisance, % TNT | 102 |

**Detonation Rate:** (c)

| | |
|---|---|
| Confinement | None |
| Condition | Cast |
| Charge Diameter, in. | 1.6 |
| Density, gm/cc | 1.65 |
| Rate, meters/second | 6600 |

DBX (Depth Bomb Explosive)

**Booster Sensitivity Test:** (e)
- Condition: Cast
- Tetryl, gm: 100
- Wax, in. for 50% Detonation: 1.35
- Wax, gm
- Density, gm/cc: 1.76

**Heat of:** (d)
- Combustion, cal/gm
- Explosion, cal/gm: 1700
- Gas Volume, cc/gm
- Formation, cal/gm
- Fusion, cal/gm

**Specific Heat:** cal/gm/°C (d)
- -5°C, density 1.75 gm/cc: 0.25

**Burning Rate:**
- cm/sec

**Thermal Conductivity:**
- cal/sec/cm/°C: $13.2 \times 10^{-4}$
- Density 1.75 gm/cc

**Coefficient of Expansion:**
- Linear, %/°C -73°-75°C: $4.5 \times 10^{-5}$
- Volume, %/°C

**Hardness, Mohs' Scale:**

**Young's Modulus:** (d)
- E', dynes/cm²: $10.4 \times 10^{10}$
- E, lb/inch²: $1.51 \times 10^{6}$
- Density, gm/cc: 1.72

**Compressive Strength:** lb/inch² (d): 3210-3380
- Density 1.78 gm/cc

**Vapor Pressure:**
- °C mm Mercury

**Decomposition Equation:**
- Oxygen, atoms/sec (Z/sec)
- Heat, kilocalorie/mole (ΔH, kcal/mol)
- Temperature Range, °C
- Phase

**Armor Plate Impact Test:**

**60 mm Mortar Projectile:**
- 50% Inert, Velocity, ft/sec
- Aluminum Fineness

**500-lb General Purpose Bombs:**

Plate Thickness, inches
- 1
- 1¼
- 1½
- 1¾

**Bomb Drop Test:**

**T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:**

Max Safe Drop, ft

**500-lb General Purpose Bomb vs Concrete:**
- Height, ft
- Trials
- Unaffected
- Low Order
- High Order

**1000-lb General Purpose Bomb vs Concrete:**
- Height, ft
- Trials
- Unaffected
- Low Order
- High Order

## DBX (Depth Bomb Explosive)

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

| **Blast (Relative to TNT):** | (d) |
|---|---|
| **Air:** | |
| Peak Pressure | 118 |
| Impulse | 127 |
| Energy | 138 |
| **Air, Confined:** | |
| Impulse | |
| **Under Water:** | |
| Peak Pressure | -- |
| Impulse | -- |
| Energy | 136 |
| **Underground:** | |
| Peak Pressure | |
| Impulse | |
| Energy | |

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Gray

**Principal Uses:** Depth charge

**Method of Loading:** Cast

**Loading Density:** gm/cc 1.61-1.69

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | |

Preparation:

DBX can be manufactured by slowly adding water-wet RDX to molten TNT melted in a steam-jacketed kettle equipped with a stirrer. When all the water has evaporated, ammonium nitrate is added and with heating and stirring continued, grained aluminum is added. The mixture is cooled with stirring continued to maintain uniformity and when suitable for pouring the mixture is cast. DBX can also be made by adding 21% ammonium nitrate and 18% aluminum to 42% cyclotol or Composition B of 50/50 RDX/TNT content plus 19% of TNT previously melted at about 100°C.

## DBX (Depth Bomb Explosive)

Origin:

DBX was developed and used by the United States and Great Britain during World War II.

References: [17]

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(c) G. H. Messerly, The Rate of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.

M. D. Hurwitz, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1946.

(d) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.

(e) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

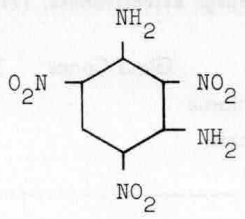
(f) Also see the following Picatinny Arsenal Technical Reports on DBX: 1585 and 1635.

[17] See footnote 1, page 10.

**Composition:**

| | % |
|---|---|
| C | 29.6 |
| H | 2.1 |
| N | 28.8 |
| O | 39.5 |

C/H Ratio 0.380




**Molecular Weight:** ($C_6H_5N_5O_6$) 243

**Oxygen Balance:**
$CO_2$ %
CO %

**Density:** gm/cc Crystal 1.83

**Melting Point:** °C (a) 290

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^D$
$n_{25}^D$
$n_{30}^D$

**Impact Sensitivity, 2 Kg Wt:**
Bureau of Mines Apparatus, cm
Sample Wt 20 mg
Picatinny Arsenal Apparatus, in. 18
Sample Wt, mg 9

**Friction Pendulum Test:**
Steel Shoe
Fiber Shoe

**Rifle Bullet Impact Test:** Trials

| | % |
|---|---|
| Explosions | |
| Partials | |
| Burned | |
| Unaffected | |

**Explosion Temperature:** °C
Seconds, 0.1 (no cap used)
1
5
10
15
20

**75°C International Heat Test:**
% Loss in 48 Hrs

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.00 |
| % Loss, 2nd 48 Hrs | 0.4 |
| Explosion in 100 Hrs | None |

**Flammability Index:**

**Hygroscopicity:** %

**Volatility:**

**Vacuum Stability Test:**
cc/40 Hrs, at
90°C
100°C
120°C
135°C
150°C

**200 Gram Bomb Sand Test:**
Sand, gm 46.6

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | ---- |
| Lead Azide | 0.20 |
| Tetryl | 0.10 |

**Ballistic Mortar, % TNT:** 100

**Trauzl Test, % TNT:**

**Plate Dent Test:**
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**Detonation Rate:**

| | |
|---|---|
| Confinement | None |
| Condition | Pressed |
| Charge Diameter, in. | 0.5 |
| Density, gm/cc | 1.65 |
| Rate, meters/second | 7500 |

# 1,3-Diamino-2,4,6-Trinitrobenzene (DATNB)

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Yellow

**Principal Uses:**

**Method of Loading:** Pressed

**Loading Density:** gm/cc
At 50,000 psi: 1.65

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | |
| Compatibility Group | |
| Exudation | None |

| | |
|---|---|
| Cook-Off Temperature: °C | 320 |
| Time, minutes | 8 |

Heat of:
Explosion, cal/gm: 2876

## 1,3-Diamino-2,4,6-Trinitrobenzene (DATNB)

Preparation:

Fifty grams (50 gm) of dry styphnic acid was added to 200 gm of anhydrous pyridine with stirring. The resulting slurry was stirred for an additional 30 minutes. The yellow product, dipyridinium styphnate, was collected by filtration and washed with approximately 100 milliliters of diethyl ether. The product was dried over phosphorus (V) oxide, at room temperature, for 5 hours. Yield of 77 gm (94%), melting point 168° to 170°C (literature melting point 173°C).

To 50 milliliters of phosphorus oxytrichloride, 29.8 gm of the dipyridinium styphnate were added in small portions, with stirring. The reaction mixture was then warmed on a steam bath for 15 minutes. This solution was quenched in 500 gm of ice water. The light yellow precipitate was separated by filtration and washed with water until the washing was neutral to litmus. Yield of 1,3-dichloro-2,4,6-trinitrobenzene 20.4 gm (98%), MP 130° to 131°C (literature MP 128°C).

A suspension of 3 gm of 1,3-dichloro-2,4,6-trinitrobenzene in 9 milliliters of absolute methanol was prepared. This slurry was cooled to 0°C, and dry ammonia was bubbled into the stirred suspension. After 20 minutes the reaction mixture was allowed to warm to room temperature, filtered by suction and washed with methanol and ether until a negative Beilstein test for chloride ion was obtained on the washings. Yield of 1,3-diamino-2,4,6-trinitrobenzene 2.5 gm (97%), MP 288° to 290°C (literature MP 285°C).

Origin:

DATNB, also called 2,4,6-trinitro-1,3-diamino-benzol or 2,4,6-trinitro-phenylenediamine-(1,3), was first obtained by Noelting and Collin in 1884 (Ber 17, 260) and also by Barr in 1888 (Ber 21, 1546) from 2,4,6-trinitroresorcin dimethylether in contact with ammoniacal alcohol for several days. J. J. Blanksma obtained the same product in 1902 by reacting either 2-chloro-2,4,6-trinitroanisole or 3-chloro-2,4,6-trinitrophenetol with ammoniacal alcohol (Rec trav chim 21, 324) and from 2,4,6-trinitroresorcin methylethyl ether with ammoniacal alcohol (Rec trav chim 27, 56 (1908)).

Meisenheimer and Patzig in 1906 prepared DATNB in the form of yellow needles, MP 280°C from 1,3,5-trinitrobenzene hydroxylamine and sodium methylate in methyl alcohol (Ber 39, 2540). The product was slightly soluble in glacial acetic acid but poorly soluble in other solvents. It decomposed into $NH_3$ and 2,4,6-trinitroresorcin when boiled with dilute NaOH or KOH (Beil 13, 60).

Körner and Contardi prepared DATNB by the reaction of either 2,4-dichloro-1,3,5-trinitrobenzene or 2,4-dibromo-1,3,5-trinitrobenzene with ammoniacal alcohol at room temperature or better by heating to 100°C (Atti R. Accad Lincei (5), 171, 473 (1908)); (5) 18 I, 101 (1909)). A method of preparation by prolonged reaction of N-nitro-N-methyl-2,3,4,6-tetranitroaniline with a saturated ammonia solution was reported in 1913 by van Romburgh and Schepers (Akad Amsterdam Versl 22, 297).

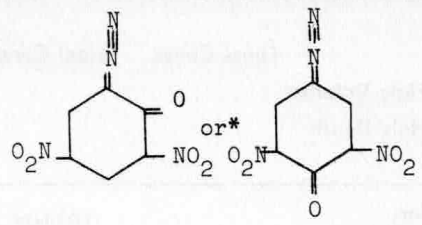
C. F. Van Duin obtained DATNB melting at 301°C by reacting a concentrated aqueous ammonia solution with N-nitro-N,N,N-trimethyl-2,4,6-trinitrophenylenediamine-(1,3) or with N-nitro-N-methyl-N-phenyl-2,4,6-trinitrophenylenediamine-(1,3) (Rec trav chim 38, 89-100 (1919)). Later Van Duin and Van Lennep reacted concentrated aqueous ammonia with 2,4,6-trinitro-3-aminoanisole or 2,4,6-trinitro-3-aminophenetol to obtain DATNB melting at 287° to 288°C (Rec trav chim 39, 147-77 (1920)). In 1927 Lorang prepared the same compound by boiling 2,4,6-trinitro-1,3-bis ( -nitroethyl ureido) benzene with water or by heating it with ammoniacal alcohol in a tube at 100°C (Rec trav chim 46, 649) (Beil E 17, E II 33).

## 1,3-Diamino-2,4,6-Trinitrobenzene (DATNB)

A recent report describes the preparation of DATNB in two steps from commercially available starting materials. First m-nitroaniline was nitrated with $H_2SO_4$-$HNO_3$ acid mixture to tetranitroaniline. The crude tetranitroaniline was converted by methanolic ammonia to diaminotrinitro-benzene in a high degree of purity. A conversion of 100 parts of m-nitroaniline into 110 parts of DATNB was obtained by this method, which can easily be carried out on a commercial scale.

**Composition:**

| | % |
|---|---|
| C | 34.3 |
| H | 0.9 |
| N | 26.7 |
| O | 38.1 |




C/H Ratio 1.056

**Molecular Weight:** ($C_6H_2N_4O_5$) 210

**Oxygen Balance:**
- $CO_2$ % -61
- CO % -15

**Density:** gm/cc Crystal 1.63

**Melting Point:** °C 157

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Impact Sensitivity, 2 Kg Wt:**
- Bureau of Mines Apparatus, cm
  Sample Wt 20 mg
- Picatinny Arsenal Apparatus, in. 4; (1 lb wt) 7
  Sample Wt, mg 15

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Detonates |
| Fiber Shoe | Detonates |

**Vacuum Stability Test:**
cc/40 Hrs, at
- 90°C
- 100°C 7.6
- 120°C
- 135°C
- 150°C

**Rifle Bullet Impact Test:** Trials

| | % |
|---|---|
| Explosions | |
| Partials | |
| Burned | |
| Unaffected | |

**200 Gram Bomb Sand Test:**

| | |
|---|---|
| Sand, gm | 47.5 |
| Black powder fuse | 45.6 |

**Explosion Temperature:** °C
Seconds, 0.1 (no cap used)

| | |
|---|---|
| 1 | 200 |
| 5 | 195 |
| 10 | 180 |
| 15 | |
| 20 | |

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | |
| Lead Azide | 0.20 |
| Tetryl | 0.10 |

**75°C International Heat Test:**
% Loss in 48 Hrs

**Ballistic Mortar, % TNT:** (a) 97

**Trauzl Test, % TNT:**

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 2.10 |
| % Loss, 2nd 48 Hrs | 2.20 |
| Explosion in 100 Hrs | None |

**Plate Dent Test:**
- Method
- Condition
- Confined
- Density, gm/cc
- Brisance, % TNT

**Flammability Index:**

**Detonation Rate:**
- Confinement
- Condition: Pressed
- Charge Diameter, in.

| Density, gm/cc | Rate, meters/second |
|---|---|
| 0.9 | 4400 |
| 1.5 | 6600 |
| 1.6 | 6900 |

**Hygroscopicity:** % 30°C, 90% RH 0.04

**Volatility:** 50°C, 30 months Unaffected

*Until it is established which picramic acid (melting point 169°C) isomer is involved (Ref: J Chem Soc, 2082, August 1949).

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Yellow needles

**Principal Uses:** Percussion caps

**Method of Loading:** Pressed

**Loading Density:** gm/cc Apparent 0.27
At 3000 psi 1.14

**Storage:**

| | |
|---|---|
| Method | Under water |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | |
| Exudation | None |

Solubility:

Soluble in nitroglycerin, nitrobenzene, aniline, pyridine, concentrated hydrochloric acid, and in most common organic solvents.

Heat of:

| | |
|---|---|
| Combustion, cal/gm | 3243 |
| Explosion, cal/gm | 820 |
| Gas Volume, cc/gm | 865 |

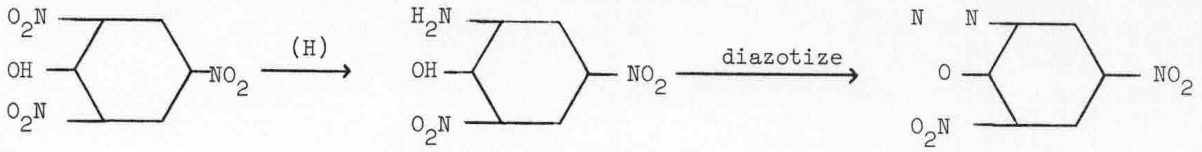
Sensitivity to Electrostatic Discharge, Joules: (b) 0.012

Solubility: gm/100 gm of the following substances: (c)

Solubility at 50°C

| Solvent | % |
|---|---|
| Ethyl acetate | 2.45 |
| Methanol | 1.25 |
| Ethanol | 2.43 |
| Ethylenedichloride | 0.79 |
| Carbon tetrachloride | trace |
| Chloroform | 0.11 |
| Benzene | 0.23 |
| Toluene | 0.15 |
| Petroleum ether | Insoluble (at 20°C) |
| Ethyl ether | 0.08 (30°C) |
| Carbon disulfide | trace (30°C) |

Preparation: (Chemistry of Powder and Explosives, Davis)




Ten gm of picramic acid is suspended in 120 cc of 5% hydrochloric acid, and under efficient agitation at about 0°C. 3.6 gm sodium nitrite in 10 cc water is dumped into the suspension. Stirring is continued for 20 minutes, the product filtered off and washed thoroughly with ice water. The dark brown product, if dissolved in acetone and precipitated in water, turns brilliant yellow.

Origin:

Discovered by Griess in 1858 (Annalen 106, 123; 113, 205 (1860) and studied extensively by L. V. Clark (Ind Eng Chem 25, 663 (1933). Developed for commercial use in 1928. This compound was patented in the United States by Professor William M. Dane.

Destruction by Chemical Decomposition:

Diazodinitrophenol is decomposed by adding the water-wet material to 100 times its weight of 10% sodium hydroxide. Nitrogen gas is evolved.

References: [18]

(a) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.

(b) F. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by

[18] See footnote 1, page 10.

Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.

(c) L. V. Clark, "Diazodinitrophenol, A Detonating Explosive," Ind Eng Chem 25, 663 (1933).

Seidell, Solubilities of Inorganic and Organic Compounds, Van Nostrand and Co., N. Y.

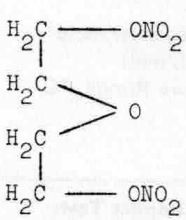
(d) Also see the following Picatinny Arsenal Technical Reports on Diazodinitrophenol:

| 0 | 2 | 4 | 5 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|
| 150 | 1352 | 34 | 355 | 827 | 318 | 2179 |
| 610 | | 214 | | | 1838 | |
| 2120 | | | | | | |

# Diethylene Glycol Dinitrate (DEGN) Liquid

**Composition:**

| | % |
|---|---|
| C | 24.5 |
| H | 4.1 |
| N | 14.3 |
| O | 57.1 |



C/H Ratio 0.143

**Molecular Weight:** $(C_4H_8N_2O_7)$ 196

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -41 |
| CO % | - 8 |

**Density:** gm/cc Liquid 1.38

**Melting Point:** °C 2

**Freezing Point:** °C

**Boiling Point:** °C Decomposes 160

**Refractive Index,** $n_{20}^D$ / $n_{25}^D$ 1.4498 / $n_{30}^D$

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 100+ |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 9 |
| Sample Wt, mg | |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Explodes |
| Fiber Shoe | |

**Vacuum Stability Test:**

cc/40 Hrs, at

| | |
|---|---|
| 90°C | |
| 100°C | 0.3cc/20 hr/gm |
| 120°C | |
| 135°C | |
| 150°C | |

**Rifle Bullet Impact Test:**

| | Trials | % |
|---|---|---|
| Explosions | | |
| Partials | | |
| Burned | | |
| Unaffected | | |

**200 Gram Bomb Sand Test:**

Sand, gm 42.2

**Explosion Temperature:** °C

Seconds, 0.1 (no cap used)

| | |
|---|---|
| 1 | |
| 5 | 237 |
| 10 | |
| 15 | |
| 20 | |

**Sensitivity to Initiation:**

Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | |
| Lead Azide | |
| Tetryl | |

**Ballistic Mortar, % TNT:** 90

**Trauzl Test, % TNT:** 77

**75°C International Heat Test:**

% Loss in 48 Hrs

**Plate Dent Test:**

| | |
|---|---|
| Method | |
| Condition | |
| Confined | |
| Density, gm/cc | |
| Brisance, % TNT | |

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 4.0 |
| % Loss, 2nd 48 Hrs | 3.0 |
| Explosion in 100 Hrs | None |

**Detonation Rate:**

| | |
|---|---|
| Confinement | |
| Condition | |
| Charge Diameter, in. | |
| Density, gm/cc | 1.38 |
| Rate, meters/second | 6760 |

**Flammability Index:**

**Hygroscopicity:** %

**Volatility:** 60°C, $mg/cm^2/hr$ 193

# Diethylene Glycol Dinitrate (DEGN) Liquid

**Booster Sensitivity Test:**
- Condition
- Tetryl, gm
- Wax, in. for 50% Detonation
- Wax, gm
- Density, gm/cc

**Heat of:**

| | |
|---|---|
| Combustion, cal/gm | 2792 |
| Explosion, cal/gm | 841 |
| Gas Volume, cc/gm | 796 |
| Formation, cal/gm | 2020 |
| Fusion, cal/gm | |

**Specific Heat:** cal/gm/°C

**Burning Rate:**
- cm/sec

**Thermal Conductivity:**
- cal/sec/cm/°C

**Coefficient of Expansion:**
- Linear, %/°C
- Volume, %/°C

**Hardness, Mohs' Scale:**

**Young's Modulus:**
- E', dynes/cm²
- E, lb/inch²
- Density, gm/cc

**Compressive Strength:** lb/inch²

**Vapor Pressure:**

| °C | mm Mercury |
|---|---|
| 20 | 0.0036 |
| 60 | 0.130 |

**Decomposition Equation:**
- Oxygen, atoms/sec (Z/sec)
- Heat, kilocalorie/mole (ΔH, kcal/mol)
- Temperature Range, °C
- Phase

**Armor Plate Impact Test:**

**60 mm Mortar Projectile:**
- 50% Inert, Velocity, ft/sec
- Aluminum Fineness

**500-lb General Purpose Bombs:**

Plate Thickness, inches

- 1
- 1¼
- 1½
- 1¾

**Bomb Drop Test:**

**T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:**

Max Safe Drop, ft

**500-lb General Purpose Bomb vs Concrete:**
- Height, ft
- Trials
- Unaffected
- Low Order
- High Order

**1000-lb General Purpose Bomb vs Concrete:**
- Height, ft
- Trials
- Unaffected
- Low Order
- High Order

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

Viscosity, centipoises:

| | |
|---|---|
| Temp, 20°C | 8.1 |

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Colorless

**Principal Uses:** Propellant compositions

**Method of Loading:**

**Loading Density:** gm/cc

**Storage:**

| | |
|---|---|
| Method | Liquid |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | |
| Exudation | |

Preparation: DEGN can be prepared with approximately 85% yield by adding diethyleneglycol to mixed acid (50% $HNO_3$, 45% $H_2SO_4$, and 5% $H_2O$). The temperature is kept at 30°C or lower. The separated DEGN is purified by washing with successive portions of water, dilute sodium carbonate solution and water until neutral.

Hydrolysis, % Acid:

| | |
|---|---|
| 10 days at 22°C | 0.003 |
| 5 days at 60°C | 0.003 |

Solubility in Water, gm/100 gm, at:

| | |
|---|---|
| 25°C | 0.40 |
| 60°C | 0.60 |

Solubility, gm/100 gm, at 25°C, in:

| | |
|---|---|
| Ether | ∞ |
| Alcohol | ∞ |
| 2:1 Ether:Alcohol | ∞ |
| Acetone | ∞ |

## Diethylene Glycol Dinitrate (DEGN) Liquid

Origin:

First prepared and studied by Wm. H. Rinkenbach in 1927 (Ind Eng Chem 19, 925 (1927) and later by Rinkenbach and H. A. Aaronson (Ind Eng Chem 23, 160 (1931)) both of Picatinny Arsenal. Used in propellant compositions by the Germans during World War II.

Destruction by Chemical Decomposition:

DEGN is decomposed by adding it slowly to 10 times its weight of 18% sodium sulfide ($Na_2S \cdot 9H_2O$). Heat is liberated by this reaction but this is not hazardous if stirring is maintained during the addition of DEGN and continued until solution is complete.

References:[19]

See the following Picatinny Arsenal Technical Reports on DEGN:

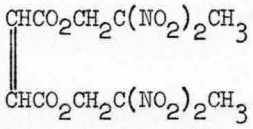
| 0 | 1 | 2 | 3 | 4 | 6 | 7 | 9 |
|---|---|---|---|---|---|---|---|
| 50 | 231 | 72 | 673 | 494 | 346 | 487 | 279 |
| 180 | 551 | 602 | 1443 | 1624 | 1516 | 1427 | 579 |
| 620 | 1391 | 1282 | | | 1616 | 1487 | 1439 |
| 1490 | 1421 | 1392 | | | 1786 | 1817 | |
| 1990 | | | | | | | |

[19]See footnote 1, page 10.

# Bis(2,2-Dinitropropyl) Fumarate (DNPF)

**Composition:**

| | % |
|---|---|
| C | 31.6 |
| H | 3.2 |
| N | 14.7 |
| O | 50.5 |



C/H Ratio

**Molecular Weight:** $(C_{10}H_{12}N_4O_{12})$ 380

**Oxygen Balance:**
- $CO_2$ % -59
- CO % -17

**Density:** gm/cc — Crystal 1.60

**Melting Point:** °C — Form I 89; Form II 86

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^D$ $n_{25}^D$ $n_{30}^D$

**Impact Sensitivity, 2 Kg Wt:**
- Bureau of Mines Apparatus, cm 100+
  Sample Wt 20 mg
- Picatinny Arsenal Apparatus, in. 18
  Sample Wt, mg 18

**Friction Pendulum Test:**
- Steel Shoe — Unaffected
- Fiber Shoe — Unaffected

**Vacuum Stability Test:**
cc/40 Hrs, at

| | |
|---|---|
| 90°C | ---- |
| 100°C | 0.66 |
| 120°C | ---- |
| 135°C | 0.91 |
| 150°C | |

**Rifle Bullet Impact Test:**

| | Trials | % |
|---|---|---|
| Explosions | | |
| Partials | | |
| Burned | | |
| Unaffected | | |

**200 Gram Bomb Sand Test:**
Sand, gm

**Explosion Temperature:** °C

| Seconds, 0.1 (no cap used) | | --- |
|---|---|---|
| 1 | | --- |
| 4 | Smokes | 250 |
| 10 | | |
| 15 | | |
| 20 | | |

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm
- Mercury Fulminate
- Lead Azide
- Tetryl

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**75°C International Heat Test:**
% Loss in 48 Hrs

**Plate Dent Test:**
- Method
- Condition
- Confined
- Density, gm/cc
- Brisance, % TNT

**100°C Heat Test:**
- % Loss, 1st 48 Hrs
- % Loss, 2nd 48 Hrs
- Explosion in 100 Hrs

**Detonation Rate:**
- Confinement
- Condition
- Charge Diameter, in.
- Density, gm/cc 1.49
- Rate, meters/second 6050

**Flammability Index:**

**Hygroscopicity:** %

**Volatility:**

# Bis(2,2-Dinitropropyl) Fumarate (DNPF)

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** White

**Principal Uses:**

**Method of Loading:** Cast

**Loading Density:** gm/cc 1.50

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | |
| Compatibility Group | |
| Exudation | None |

Heat of:

| | |
|---|---|
| Combustion, cal/gm | 3070 (calculated) |
| Detonation, cal/gm | 767 (calculated) |

Viscosity, poises:

| | |
|---|---|
| Temp, 98.9°C | 0.586 |
| 106.5°C | 0.435 |

Liquid Density, gm/cc:

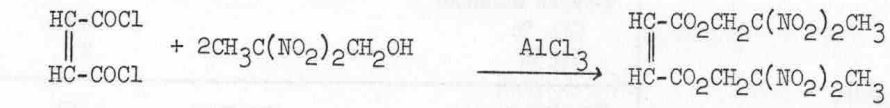
| | |
|---|---|
| Temp, 98.9°C | 1.382 |
| 106.5°C | 1.375 |

Origin:

Synthesized in 1952 by M. E. Hill of the U.S. Naval Ordnance Laboratory, White Oak, Maryland.

## Bis(2,2-Dinitropropyl) Fumarate (DNPF)

Preparation: (a, b)



3.3 mol fumaryl chloride | 7.3 mol 2,2-dinitropropanol | 1.6 mol aluminum chloride | 83% yield bis(dinitropropyl) fumarate

Dinitropropanol was mixed with chloroform (1320 milliliters) and the mixture heated to boiling. The distillate was collected in a water separator. At first the distillate was cloudy and this was dried with calcium chloride before being returned to the system. When no more water was collected in the water separator, the mixture was cooled to room temperature and the separator removed. Fumaryl chloride was introduced, followed by the aluminum chloride which was added in four equal portions. Air was blown into the flask for a minute to effect mixing, and the reaction sustained itself without the addition of heat for one hour. Steam was gradually introduced so that the reflux temperature was reached 2-1/2 hours after the beginning of the reaction. After 3 hours of reflux, the hot liquid was poured into a bucket. As cooling took place the slurry was vigorously agitated until it finally set up at room temperature. This material was broken up and mixed with dilute ice cold HCl. The solid product was collected on a sintered funnel, washed with water and with hexane. The crude material was recrystallized from methanol to give a product melting at 86°C (uncorrected), but after storage for several days the melting point was 89°C.

References:[20]

(a) M. E. Hill, Preparation and Properties of 2,2-Dinitropropanol Esters, NAVORD Report No. 2497, 3 July 1952.

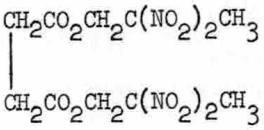
(b) D. L. Kouba and H. D. McNeil, Jr., Hercules Report on High Explosives, Navy Contract NOrd-11280, Task A, 26 May 1954.

[20] See footnote 1, page 10.

# Bis(2,2-Dinitropropyl) Succinate (DNPS)

**Composition:**

| | % |
|---|---|
| C | 31.4 |
| H | 3.7 |
| N | 14.7 |
| O | 50.2 |



C/H Ratio 0.250

**Molecular Weight:** $(C_{10}H_{14}N_4O_{12})$ 382

**Oxygen Balance:**
- $CO_2$ % -63
- CO % -21

**Density:** gm/cc Crystal 1.51

**Melting Point:** °C 86

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^D$ $n_{25}^D$ $n_{30}^D$

**Impact Sensitivity, 2 Kg Wt:**
- Bureau of Mines Apparatus, cm
- Sample Wt 20 mg
- Picatinny Arsenal Apparatus, in.
- Sample Wt, mg

**Vacuum Stability Test:**
cc/40 Hrs, at

| | |
|---|---|
| 90°C | ---- |
| 100°C | 0.10 |
| 120°C | |
| 135°C | |
| 150°C | |

**Friction Pendulum Test:**
- Steel Shoe
- Fiber Shoe

**Rifle Bullet Impact Test:**

| | Trials | % |
|---|---|---|
| Explosions | | |
| Partials | | |
| Burned | | |
| Unaffected | | |

**200 Gram Bomb Sand Test:**
- Sand, gm

**Explosion Temperature:** °C

| Seconds, 0.1 (no cap used) | --- |
|---|---|
| 1 | --- |
| 5 | >400 |
| 10 | |
| 15 | |
| 20 | |

**Sensitivity to Initiation:**
- Minimum Detonating Charge, gm
  - Mercury Fulminate
  - Lead Azide
  - Tetryl

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**75°C International Heat Test:**
- % Loss in 48 Hrs

**Plate Dent Test:**
- Method
- Condition
- Confined
- Density, gm/cc
- Brisance, % TNT

**100°C Heat Test:**
- % Loss, 1st 48 Hrs
- % Loss, 2nd 48 Hrs
- Explosion in 100 Hrs

**Detonation Rate:**
- Confinement
- Condition
- Charge Diameter, in.
- Density, gm/cc
- Rate, meters/second

**Flammability Index:**

**Hygroscopicity:** %

**Volatility:**

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** White

**Principal Uses:**

**Method of Loading:** Cast

**Loading Density:** gm/cc

**Storage:**

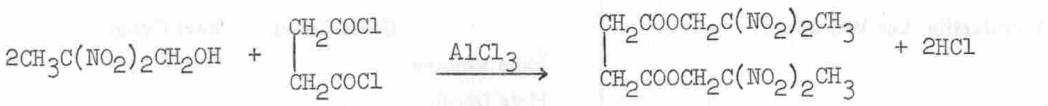
| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | |
| Compatibility Group | |
| Exudation | None |

Origin:

Synthesized in 1953 by M. E. Hill of the U.S. Naval Ordnance Laboratory, White Oak, Maryland.

## Bis(2,2-Dinitropropyl) Succinate (DNPS)

Preparation: (a)




dinitropropanol — succinyl chloride — aluminum chloride — bis(2,2-dinitropropyl) succinate

A methylene chloride solution of dinitropropanol (0.02 mol in 15 milliliters) was mixed with 0.01 mol of succinyl chloride. To this solution 0.003 mol of crushed anhydrous aluminum chloride was added. It was necessary to cool the reaction vessel due to the vigorousness of the reaction. After 25 minutes at room temperature the reaction solution was refluxed 1-1/2 hours. Fine needle-like crystals formed upon cooling and adding hexane. The crystals were slurried in dilute hydrochloric acid and on recrystallization from methanol gave a 93% yield of DNPS (melting point 85° to 85.6°C).

References:[21]

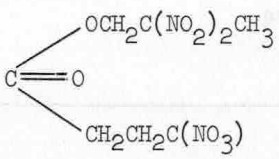
(a) M. E. Hill, Synthesis of New High Explosives, NAVORD Report No. 2965, 1 April 1953.

[21]See footnote 1, page 10.

## 2,2-Dinitropropyl-4,4,4-Trinitrobutyrate (DNPTB)

**Composition:**

| | % |
|---|---|
| C | 23.6 |
| H | 2.5 |
| N | 19.7 |
| O | 54.2 |
| C/H Ratio | |




**Molecular Weight:** $(C_7H_9N_5O_{12})$ 355

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -29 |
| CO % | +2.3 |

**Density:** gm/cc Crystal 1.68

**Melting Point:** °C Form I 11 Form II 95 Form III 59

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Impact Sensitivity, 2 Kg Wt:**
Bureau of Mines Apparatus, cm
Sample Wt 20 mg
Picatinny Arsenal Apparatus, in.
Sample Wt, mg

**Vacuum Stability Test:**
cc/40 Hrs, at

| | |
|---|---|
| 90°C | --- |
| 100°C | 0.5 |
| 120°C | |
| 135°C | |
| 150°C | |

**Friction Pendulum Test:**
Steel Shoe
Fiber Shoe

**Rifle Bullet Impact Test:** Trials

| | % |
|---|---|
| Explosions | |
| Partials | |
| Burned | |
| Unaffected | |

**200 Gram Bomb Sand Test:**
Sand, gm

**Explosion Temperature:** °C

| Seconds, 0.1 (no cap used) | --- |
|---|---|
| 1 | --- |
| 5 | 300 |
| 10 | |
| 15 | |
| 20 | |

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm
Mercury Fulminate
Lead Azide
Tetryl

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**75°C International Heat Test:**
% Loss in 48 Hrs

**Plate Dent Test:**
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**100°C Heat Test:**
% Loss, 1st 48 Hrs
% Loss, 2nd 48 Hrs
Explosion in 100 Hrs

**Detonation Rate:**
Confinement
Condition
Charge Diameter, in.
Density, gm/cc 1.67
Rate, meters/second 7600

**Flammability Index:**

**Hygroscopicity:** %

**Volatility:**

# 2,2-Dinitropropyl-4,4,4-Trinitrobutyrate (DNPTB)

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** White

**Principal Uses:**

**Method of Loading:** Cast

**Loading Density:** gm/cc 1.67

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | |
| Compatibility Group | |
| Exudation | None |

Heat of: (c)

| Transition, cal/gm | Solvent $CCl_4$ | Solvent DMF |
|---|---|---|
| I ⟶ III | 6.2 | 4.8 |
| II ⟶ I | -16.6 | -22.0 |

Heat of Solution, 30°C:

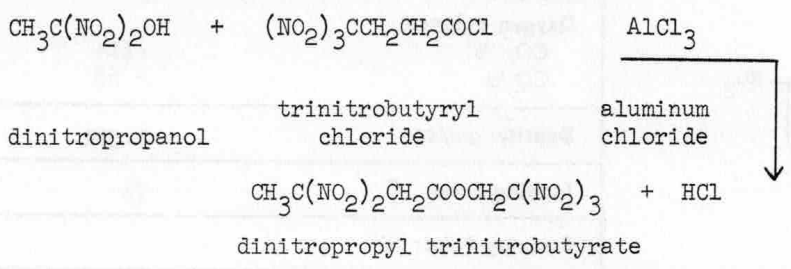
| Material | ΔH Solution, cal/gm $CCl_4$ | ΔH Solution, cal/gm DMF |
|---|---|---|
| Form III | 29.5 | 8.1 |
| Form I | 35.6 | 12.8 |
| Form II | 19.1 | -9.1 |

Origin:

Synthesized in 1952 by M. E. Hill of the U.S. Naval Ordnance Laboratory, White Oak, Maryland.

## 2,2-Dinitropropyl-4,4,4-Trinitrobutyrate (DNPTB)

Preparation: (a, b)




Dinitropropanol, trinitrobutyryl chloride and aluminum chloride were slowly mixed in carbon tetrachloride at 60°C. This mixture was refluxed at 75°C for two hours. After the reaction was completed, the mixture was cooled and the crystalline product separated and purified. Water in the dinitropropanol was removed by azeotropic distillation before the acid chloride was added. The purified product had a melting point of 95° to 96°C.

Crystallographic Data: (c)

Three distinct crystallographic modifications of DNPTB have been observed. These polymorphs have been characterized by means of X-ray diffraction and microscopic observation. Form I crystallizes from solution in carbon tetrachloride, chloroform, acetone, chloroform-hexane, acetone-water, or methanol-water at room temperature. Prolonged standing of Form I at room temperature under the mother liquor promotes a transition to Form II. Upon solidification of molten DNPTB, Form II is always observed.

Linear Rate of Transformation of Form II to Form I (c)

| Temperature, °C | Average Rate, sq inch/hour | Standard Deviation | Average Rate, mm/hour |
|---|---|---|---|
| 15 | 0.347 | 0.036 | 0.012 |
| 20 | 0.435 | 0.025 | 0.128 |
| 25 | 0.452 | 0.048 | 0.133 |
| 30 | 0.475 | 0.049 | 0.140 |
| 35 | 0.253 | 0.037 | 0.075 |

Both Forms I and III gave very erratic sensitivity values. The high temperature polymorph, Form II of DNPTB, gave consistent sensitivity values.

References:[22]

(a) M. E. Hill, Preparation and Properties of 2,2-Dinitropropanol Esters, NAVORD Report No. 2497, 3 July 1952.

(b) W. B. Hewson, Hercules Report on High Explosives, Navy Contract NOrd-11280, Task A, 18 October 1954.

(c) J. R. Holden and J. Wenograd, Physical Properties of an Experimental Castable Explosive 2,2-Dinitropropyl 2,4,4-Trinitrobutyrate DNPTB, NAVORD Report No. 4427, 11 December 1956.

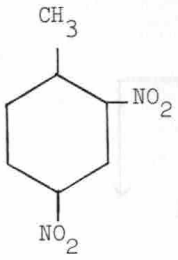
[22] See footnote 1, page 10.

# 2,4-Dinitrotoluene (DNT)

**Composition:**

| | % |
|---|---|
| C | 46.3 |
| H | 3.3 |
| N | 15.4 |
| O | 35.0 |

C/H Ratio 0.579




**Molecular Weight:** ($C_7H_6N_2O_4$) 1.82

**Oxygen Balance:**
- $CO_2$ % -114
- CO % - 53

**Density:** gm/cc 1.521

**Melting Point:** °C 71

**Freezing Point:** °C

**Boiling Point:** °C Decomposes 300

**Refractive Index,** $n_{20}^D$ $n_{25}^D$ $n_{30}^D$

**Impact Sensitivity, 2 Kg Wt:**
- Bureau of Mines Apparatus, cm
  - Sample Wt 20 mg
- Picatinny Arsenal Apparatus, in.
  - Sample Wt, mg

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | Unaffected |

**Vacuum Stability Test:**
cc/40 Hrs, at
- 90°C
- 100°C
- 120°C 0.04
- 135°C
- 150°C

**Rifle Bullet Impact Test:**

| | Trials | % |
|---|---|---|
| Explosions | | 0 |
| Partials | | 0 |
| Burned | | 0 |
| Unaffected | | 100 |

**200 Gram Bomb Sand Test:**
Sand, gm 19.3

**Explosion Temperature:** °C
Seconds, 0.1 (no cap used)
- 1
- 5 Decomposes 310
- 10
- 15
- 20

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm
- Mercury Fulminate
- Lead Azide 0.20
- Tetryl 0.25

**Ballistic Mortar, % TNT:** (a) 71

**Trauzl Test, % TNT:** (b) 64

**75°C International Heat Test:**
% Loss in 48 Hrs

**Plate Dent Test:**
- Method
- Condition
- Confined
- Density, gm/cc
- Brisance, % TNT

**100°C Heat Test:**
- % Loss, 1st 48 Hrs
- % Loss, 2nd 48 Hrs
- Explosion in 100 Hrs

**Detonation Rate:**
- Confinement
- Condition
- Charge Diameter, in.
- Density, gm/cc
- Rate, meters/second

**Flammability Index:**

**Hygroscopicity:** % 25°C, 100% RH 0.00

**Volatility:**

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**Fragment Velocity:** ft/sec

At 9 ft

At 25½ ft

Density, gm/cc

**Blast (Relative to TNT):**

**Air:**

Peak Pressure

Impulse

Energy

**Air, Confined:**

Impulse

**Under Water:**

Peak Pressure

Impulse

Energy

**Underground:**

Peak Pressure

Impulse

Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Yellow

**Principal Uses:** Ingredient of propellant powder, dynamites and plastic explosives

**Method of Loading:** Pressed, extruded or cast composition

**Loading Density:** gm/cc Variable

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 12 |
| Compatibility Group | Group D |
| Exudation | |

65.5°C KI Test:

Minutes 60+

Heat of:

Combustion, cal/gm (b) 1545

Thermal Conductivity:

cal/sec/cm/°C
Density 1.322 gm/cc $6.28 \times 10^{-4}$

## 2,4-Dinitrotoluene (DNT)

Preparation:

See TNT.

Solubility: gm/100 gm of the following substances:

| 30% Ethyl Alcohol | | Nitroglycerin | | Water | |
|---|---|---|---|---|---|
| °C | % | °C | % | °C | % |
| 25 | 0.16 | 20 | 30 | 22 | 0.027 |
| 35 | 0.29 | | | 50 | 0.037 |
| 45 | 0.49 | | | 100 | 0.254 |
| 55 | 0.77 | | | | |
| 60 | 1.03 | | | | |

Solubility at 15°C, in:

| Solvent | % | Solvent | % |
|---|---|---|---|
| $CHCl_3$ | 65.076 | $C_2H_5OH$ (absolute) | 3.039 |
| $CCl_4$ | 2.431 | Ether (absolute) | 9.422 |
| $C_6H_6$ | 60.644 | Acetone | 81.901 |
| Toluol | 45.470 | Ethyl acetate | 57.929 |
| $CH_3OH$ | 5.014 | $CS_2$ | 2.306 |
| $C_2H_5OH$ (96%) | 1.916 | Pyridine | 76.810 |

Origin:

Occurs as 75% of the products obtained on the nitration of toluene, the remaining 25% being mainly 2,6-DNT and other isomers of DNT. Also occurs as an impurity in crude TNT obtained by standard manufacturing process. Used in explosive mixtures at least since 1931.

References:[23]

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) A. H. Blatt, Compilation of Data on Organic Explosives, OSRD Report No. 2014, 29 February 1944.

(c) Report AC-2861.

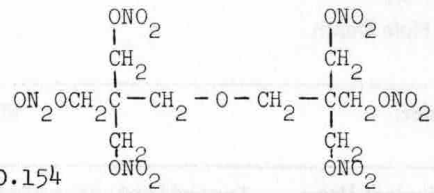
(d) Also see the following Picatinny Arsenal Technical Reports on DNT:

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 810 | 1351 | 72 | 43 | 394 | 1615 | 186 | 97 | 768 | 69 |
| 1830 | 1501 | 372 | 233 | 804 | 2125 | 1556 | 817 | 938 | 149 |
| | 1651 | 922 | 343 | 1044 | | 1816 | 837 | 1538 | 249 |
| | 1781 | 1142 | 673 | 1084 | | 1896 | | | 279 |
| | 1821 | 1672 | 1023 | 1094 | | | | | 779 |
| | 2031 | 1692 | 1663 | 1164 | | | | | 1749 |
| | 2221 | | 1743 | 1324 | | | | | |
| | | | 2013 | 1464 | | | | | |
| | | | | 1524 | | | | | |
| | | | | 1674 | | | | | |
| | | | | 1754 | | | | | |
| | | | | 2094 | | | | | |

[23] See footnote 1, page 10.

**Composition:**

| | % |
|---|---|
| C | 21.7 |
| H | 2.9 |
| N | 15.2 |
| O | 60.2 |



C/H Ratio 0.154

**Molecular Weight:** $(C_{10}H_{16}N_6O_{19})$ 554

**Oxygen Balance:**
- $CO_2$ % -26
- CO % + 3

**Density:** gm/cc Crystal 1.63

**Melting Point:** °C 73.7

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^D$ $n_{25}^D$ $n_{30}^D$

**Impact Sensitivity, 2 Kg Wt:**
- Bureau of Mines Apparatus, cm 14
  Sample Wt 20 mg
- Picatinny Arsenal Apparatus, in. 4
  Sample Wt, mg 10

**Friction Pendulum Test:**
- Steel Shoe Explodes
- Fiber Shoe Unaffected

**Vacuum Stability Test:**
cc/40 Hrs, at
- 90°C
- 100°C 3.7
- 120°C 11+
- 135°C
- 150°C

**Rifle Bullet Impact Test:** Trials %
- Explosions
- Partials
- Burned
- Unaffected

**200 Gram Bomb Sand Test:**
- Sand, gm 57.4

**Explosion Temperature:** °C
Seconds, 0.1 (no cap used)

| | | |
|---|---|---|
| 1 | | 300 |
| 5 | Explodes | 255 |
| 10 | | |
| 15 | | |
| 20 | | |

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm
- Mercury Fulminate
- Lead Azide
- Tetryl

**Ballistic Mortar, % TNT:** (a) 142

**Trauzl Test, % TNT:** (b) 128

**75°C International Heat Test:**
- % Loss in 48 Hrs

**Plate Dent Test:**
- Method
- Condition
- Confined
- Density, gm/cc
- Brisance, % TNT

**100°C Heat Test:**
- % Loss, 1st 48 Hrs 0.11
- % Loss, 2nd 48 Hrs 0.10
- Explosion in 100 Hrs None

**Detonation Rate:** (c)
- Confinement Copper tube
- Condition Pressed
- Charge Diameter, in. 0.39
- Density, gm/cc 1.59
- Rate, meters/second 7410

**Flammability Index:**

**Hygroscopicity:** % 0.03

**Volatility:**

# Dipentaerythritol Hexanitrate (DPEHN)

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**Fragment Velocity:** ft/sec

At 9 ft

At 25½ ft

Density, gm/cc

**Blast (Relative to TNT):**

**Air:**

Peak Pressure

Impulse

Energy

**Air, Confined:**

Impulse

**Under Water:**

Peak Pressure

Impulse

Energy

**Underground:**

Peak Pressure

Impulse

Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** White

**Principal Uses:** Ingredient of priming compositions

**Method of Loading:** Pressed

**Loading Density:** gm/cc

At 3000 to 4000 psi 1.59

**Storage:**

Method: Dry

Hazard Class (Quantity-Distance): Class 9

Compatibility Group

Exudation

Preparation: (Chemistry of Powder and Explosives, Davis)

$$2(HO\text{-}CH_2)_4C \xrightarrow{\text{Dehydration}} (HO\text{-}CH_2)_3C\text{-}O\text{-}C(CH_2\text{-}OH)_3 \longrightarrow (O_2NO\text{-}CH_2)_3C\text{-}O\text{-}C(CH_2\text{-}ONO_2)_3$$

Dipentaerythritol Hexanitrate is procured in the pure state (melting point 72°C) by fractional crystallization of crude PETN from moist acetone.

Origin: Formed as an impurity in the preparation of PETN. Properties first described by W. Frederick and W. Brün in 1930 (Berichte 63, 2861 (1930); Z. ges Schiess-Sprengstoffw 27, 73-6, 125-7, 156-8 (1932)).

Heat of:

Combustion, cal/gm 2260

(b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(c) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

(d) F. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.

(e) Various sources in the open literature.

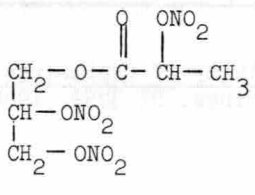
(f) Also see the following Picatinny Arsenal Technical Reports on Explosive D:

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 340 | 1441 | 132 | 843 | 694 | 65 | 266 | 1737 | 328 | 1729 |
| 870 | 1651 | 582 | | 704 | 425 | 556 | 1797 | 838 | 1759 |
| 1380 | | 1172 | | 874 | 1585 | 796 | | 1838 | |
| | | 1352 | | 1234 | 1655 | 986 | | | |
| | | 1372 | | 1724 | 1725 | 1466 | | | |
| | | 1492 | | | 1885 | 1796 | | | |
| | | | | | 1895 | | | | |

# Glycerol Monolactate Trinitrate (GLTN) Liquid

**Composition:**

| | % |
|---|---|
| C | 24.1 |
| H | 3.0 |
| N | 14.1 |
| O | 58.8 |



C/H Ratio 0.180

**Molecular Weight:** $(C_6H_9N_3O_{11})$ 299

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -30 |
| CO % | 3 |

**Density:** gm/cc Liquid 1.47

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ 1.464 $n_{30}^{D}$

**Impact Sensitivity, 2 Kg Wt:**
Bureau of Mines Apparatus, cm 15 (1 lb wt); 42
Sample Wt 20 mg
Picatinny Arsenal Apparatus, in.
Sample Wt, mg

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | Unaffected |

**Vacuum Stability Test:**
cc/40 Hrs, at
90°C
100°C 5.9
120°C
135°C
150°C

**Rifle Bullet Impact Test:** Trials

| | % |
|---|---|
| Explosions | |
| Partials | |
| Burned | |
| Unaffected | |

**200 Gram Bomb Sand Test:**
Sand, gm 13.1

**Explosion Temperature:** °C
Seconds, 0.1 (no cap used)

| | |
|---|---|
| 1 | |
| 5 | 223 |
| 10 | |
| 15 | |
| 20 | |

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm
Mercury Fulminate
Lead Azide
Tetryl

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**75°C International Heat Test:**
% Loss in 48 Hrs

**Plate Dent Test:**
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 2.5 |
| % Loss, 2nd 48 Hrs | 1.8 |
| Explosion in 100 Hrs | None |

**Detonation Rate:**
Confinement
Condition
Charge Diameter, in.
Density, gm/cc
Rate, meters/second

**Flammability Index:**

**Hygroscopicity:** %

**Volatility:** 60°C, $mg/cm^2/hr$ 28

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**Fragment Velocity:** ft/sec

At 9 ft

At 25½ ft

Density, gm/cc

**Blast (Relative to TNT):**

**Air:**

Peak Pressure

Impulse

Energy

**Air, Confined:**

Impulse

**Under Water:**

Peak Pressure

Impulse

Energy

**Underground:**

Peak Pressure

Impulse

Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:**

**Principal Uses:** Gelatinizer for nitrocellulose

**Method of Loading:**

**Loading Density:** gm/cc

**Storage:**

| | |
|---|---|
| Method | Liquid |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | |
| Exudation | |

| | |
|---|---|
| Hydrolysis, % Acid: | |
| 10 days at 22°C | 0.021 |
| 5 days at 60°C | 0.014 |
| Solubility in Water, gm/100 gm, at: | |
| 25°C | < 0.01 |
| 60°C | < 0.015 |
| Solubility, gm/100 gm, at 25°C, in: | |
| Ether | ∞ |
| 2:1 Ether:Alcohol | ∞ |
| Acetone | ∞ |
| Heat of: | |
| Combustion, cal/gm | 2407 |

## Glycerol Monolactate Trinitrate (GLTN) Liquid

Preparation:

Glycerol monolactate (GML) is prepared by heating a glycerol lactic acid mixture containing 4% excess lactic acid at 116°C for 112 hours with dry air bubbling through the liquid. The product which contains 0.67% free acid is carefully mixed with 6 parts of 40/60 $HNO_3/H_2SO_4$ maintained at 20°C, stirred for 1 hour, cooled to 5°C, and poured on ice. It is extracted with ether, water-washed, adjusted to pH 7 by shaking with a sodium bicarbonate solution, and again water-washed three times. It is then dried with calcium chloride, filtered and freed of ether by bubbling with air until minimal loss in weight is obtained. The product has a nitrate-nitrogen content of 13.43% (theoretical 14.1% N). Another batch, prepared from GML obtained from glycerol-lactic acid containing 6.5% excess glycerol, had a nitrate-nitrogen content of 14.30%, corresponding to a mixture containing 5.5% nitroglycerin. It is not considered practicable to prepare the pure GLTN.

Origin:

The preparation of a nitrated ester of lactic acid and glycerol, by nitrating a glyceryl lactate with nitric and sulfuric acids, for use in explosives, was reported in 1931 by Charles Stine and Charles Burke (U. S. Patent 1,792,515).

The preparation of glycerol monolactate by heating glycerol with equimolar proportions of a lactic acid ester of an alcohol boiling below 100°C (ethyl lactate) was patented by Richie H. Locke in 1936 (British Patent 456,525 and U. S. Patent 2,087,980).

Reference:[31]

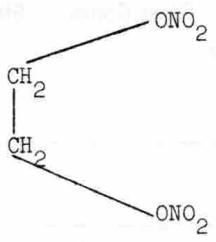
(a) P. F. Macy and A. A. Saffitz, Explosive Plasticizers for Nitrocellulose, PATR No. 1616, 22 July 1946.

[31]See footnote 1, page 10.

# Glycol Dinitrate (GDN) Liquid

**Composition:**

| | % |
|---|---|
| C | 15.8 |
| H | 2.6 |
| N | 18.4 |
| O | 63.2 |




C/H Ratio 0.092

**Molecular Weight:** $(C_2H_4N_2O_6)$ 152

**Oxygen Balance:**
$CO_2$ % 0.0
CO % 21

**Density:** gm/cc Liquid, 25°C 1.48

**Melting Point:** °C -20

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^D$
$n_{25}^D$ 1.4452
$n_{30}^D$

**Impact Sensitivity, 2 Kg Wt:**
Bureau of Mines Apparatus, cm 4 (1 lb wt); 56
Sample Wt 20 mg
Picatinny Arsenal Apparatus, in.
Sample Wt, mg

**Friction Pendulum Test:**
Steel Shoe
Fiber Shoe

**Vacuum Stability Test:**
cc/40 Hrs, at
90°C
100°C
120°C
135°C
150°C

**Rifle Bullet Impact Test:** Trials / %
Explosions
Partials
Burned
Unaffected

**200 Gram Bomb Sand Test:**
Sand, gm

**Explosion Temperature:** °C
Seconds, 0.1 (no cap used)
1
5 Explodes 257
10
15
20

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm
Mercury Fulminate
Lead Azide
Tetryl

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**75°C International Heat Test:**
% Loss in 48 Hrs

**Plate Dent Test:**
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**100°C Heat Test:**
% Loss, 1st 48 Hrs
% Loss, 2nd 48 Hrs
Explosion in 100 Hrs

**Detonation Rate:**

| | |
|---|---|
| Confinement | Glass tube |
| Condition | Liquid |
| Charge Diameter, in. | 10 |
| Density, gm/cc | 1.485 |
| Rate, meters/second | 7300 and 2050 |

**Flammability Index:**

**Hygroscopicity:** % 30°C, 90% RH 0.00

**Volatility:**

# Glycol Dinitrate (GDN) Liquid

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Yellow

**Principal Uses:** Ingredient of nonfreezing dynamite

**Method of Loading:**

**Loading Density:** gm/cc

**Storage:**

| | |
|---|---|
| Method | Liquid |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | |
| Exudation | |

Solubility in 1000 cc Water:

| Temp, °C | Grams |
|---|---|
| 15 | 6.2 |
| 20 | 6.8 |
| 50 | 9.2 |

Viscosity, centipoises:

| Temp, 20°C | 4.2 |
|---|---|

Vapor Pressure:

| °C | mm Mercury |
|---|---|
| 0 | 0.0044 |
| 20 | 0.038 |
| 40 | 0.26 |
| 60 | 1.3 |
| 80 | 5.9 |
| 100 | 22.0 |

Heat of:

| | | |
|---|---|---|
| Combustion, cal/gm | | 1764 |
| Formation, cal/gm | (b) | 366 |

Preparation:

Glycol dinitrate (ethylene glycol dinitrate, dinitroglycol, nitroglycol, dinitrodimethyleneglycol) may be prepared by nitration of ethylene glycol, $HOCH_2CH_2OH$, with a mixed nitric acid in the same apparatus that is used for the preparation of nitroglycerin. The glycol is prepared by synthesis from ethylene, and ethylene chlorohydrin:

$$CH_2 = CH_2 \xrightarrow{HOCl} HOCH_2CH_2Cl \xrightarrow[NaHCO_3]{H_2O} HOCH_2CH_2OH$$

Origin:

Henry was the first to prepare and identify glycol dinitrate (Ber 3, 529 (1870) and Ann chim phys [4] 27, 243 (1872) but Kekulé had previously nitrated ethylene and obtained an unstable oil which he supposed to be glycol nitrate-nitrate. No immediate practical use was made of glycol dinitrate because glycol itself was relatively rare and expensive at the time. It was 1904 before a patent was granted covering the use of GDN as an explosive (DRP 179,789), but it was seven years later before its actual use as an explosive was recorded (Mém poudr 16 (1911) p. 214). The principal physical properties of GDN were determined or recorded by Rinkenbach (Ref b).

References:[32]

(a) Ph. Naoum, Nitroglycerin and Nitroglycerin Explosives, translation, E. M. Symmes, The Williams and Wilkins Company, Baltimore (1928), p. 224.

(b) Wm. H. Rinkenbach, "The Properties of Glycol Dinitrate," Ind Eng Chem 18, 1195 (1926).

(c) Wm. H. Rinkenbach, "Glycol Dinitrate in Dynamite Manufacture," Chem Met Eng, 34, 296 (1927).

(d) Wm. H. Rinkenbach, Application of the Vacuum Stability Test to Nitroglycerin and Nitroglycerin Explosives, PATR 1624, 27 August 1946.

[32]See footnote 1, page 10.

H-6

**Composition:**

| | % |
|---|---|
| RDX | 45 |
| TNT | 30 |
| Aluminum | 20 |
| D-2 Wax | 5 |
| Calcium Chloride, added | 0.5 |
| C/H Ratio | |

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | -- |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in.(c) | 14 |
| Sample Wt, mg | 18 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | --- |

**Rifle Bullet Impact Test:** Trials (b)

| | % |
|---|---|
| Explosions | 80 |
| Partials | -- |
| Burned | -- |
| Unaffected | 20 |

**Explosion Temperature:** °C (a)

| | |
|---|---|
| Seconds, 0.1 (no cap used) | --- |
| 1 | --- |
| 5 | 610(min) (c) |
| 10 | |
| 15 | |
| 20 | |

**75°C International Heat Test:**
% Loss in 48 Hrs

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.78 |
| % Loss, 2nd 48 Hrs | 0.00 |
| Explosion in 100 Hrs | None |

**Flammability Index:**

**Hygroscopicity:** % 30°C, 95% RH, 7 days 2.01
71°C, 95% RH, 7 days 1.77

**Volatility:**

**Molecular Weight:** 93

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -66 |
| CO % | -36 |

**Density:** gm/cc Cast 1.74

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$
$n_{25}^{D}$
$n_{30}^{D}$

**Vacuum Stability Test:**
cc/40 Hrs, at

| | |
|---|---|
| 90°C | ---- |
| 100°C | 0.47 |
| 120°C | |
| 135°C | |
| 150°C | |

**200 Gram Bomb Sand Test:**

| | |
|---|---|
| Sand, gm | 49.5 |

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | ---- |
| Lead Azide | 0.20 |
| Tetryl | 0.10 |

**Ballistic Mortar, % TNT:** (d) 135

**Trauzl Test, % TNT:**

**Plate Dent Test:**
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**Detonation Rate:** (a, b)

| | |
|---|---|
| Confinement | None |
| Condition | Cast |
| Charge Diameter, in. | 1.0 |
| Density, gm/cc | 1.71 |
| Rate, meters/second | 7191 |

**Booster Sensitivity Test:**
Condition
Tetryl, gm
Wax, in. for 50% Detonation
Wax, gm
Density, gm/cc

**Heat of:**

| | |
|---|---|
| Combustion, cal/gm | 3972 |
| Explosion, cal/gm | 923 |
| Gas Volume, cc/gm | 733 |
| Formation, cal/gm | |
| Fusion, cal/gm 78°C (b) | 10.25 |

**Specific Heat:** cal/gm/°C (b)

| | |
|---|---|
| 30°C | 0.269 |
| 50°C | 0.268 |

**Burning Rate:**
cm/sec

**Thermal Conductivity:** (b)
cal/sec/cm/°C 35°C $1.10 \times 10^{-3}$

**Coefficient of Expansion:**
Linear, $\Delta\ell$/inch

| | |
|---|---|
| 0°C | $40 \times 10^{-4}$ |
| 35°C | $83 \times 10^{-4}$ |
| 70°C | $131 \times 10^{-4}$ |

**Hardness, Mohs' Scale:**

**Young's Modulus:** (b)

| | |
|---|---|
| E', dynes/cm² | $9.0 \times 10^{9}$ |
| E, lb/inch² | $1.30 \times 10^{5}$ |
| Density, gm/cc | 1.71 |

**Compressive Strength:** lb/inch² See below

**Vapor Pressure:**
°C mm Mercury

Compressive Strength: lb/inch²

| | |
|---|---|
| Density, gm/cc | 1083 |
| Ultimate deformation, % | 1.71 |
| | 1.32 |

**Decomposition Equation:**
Oxygen, atoms/sec (Z/sec)
Heat, kilocalorie/mole (ΔH, kcal/mol)
Temperature Range, °C
Phase

**Armor Plate Impact Test:**

**60 mm Mortar Projectile:**
50% Inert, Velocity, ft/sec
Aluminum Fineness

**500-lb General Purpose Bombs:**

Plate Thickness, inches

1
1¼
1½
1¾

**Bomb Drop Test:**

**T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:**

Max Safe Drop, ft

**500-lb General Purpose Bomb vs Concrete:**

Height, ft
Trials
Unaffected
Low Order
High Order

**1000-lb General Purpose Bomb vs Concrete:**

Height, ft
Trials
Unaffected
Low Order
High Order

**Fragmentation Test:** (b)

**90 mm HE, M71 Projectile, Lot** EGS-1-17:

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

| | |
|---|---|
| For Composition B | 998 |
| For Subject HE | 714 |
| For 80/20 Tritonal | 616 |

**3 inch HE, M42A1 Projectile, Lot KC-5:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**Fragment Velocity:** ft/sec

At 9 ft

At 25½ ft

Density, gm/cc

**Blast (Relative to TNT):** (a)

**Air:** 3.25" diameter sphere

| | |
|---|---|
| Peak Pressure Δ psi Catenary | 25.4 |
| Impulse NFOC Pendulum | 19.8 |
| Energy | ---- |

**Air, Confined:**

Impulse

**Under Water:**

Peak Pressure

Impulse

Energy

**Underground:**

Peak Pressure

Impulse

Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Gray

**Principal Uses:** HE charge

**Method of Loading:** Cast

**Loading Density:** gm/cc 1.71

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | None |

Effect of Altitude, Charge Diameter and Degree of Confinement on Detonation Velocity*

(Reference e)

| Explosive | Simulated Altitude, Feet | One-Inch Column | | Two-Inch Column | |
|---|---|---|---|---|---|
| | | Confined m/s | Unconfined m/s | Confined m/s | Unconfined m/s |
| TNT, density, gm/cc 1.59 | Ground | 6820 | 6720 | 6670 | 5270 |
| | 30,000 | 6660 | 6930(2) | 6610 | 6760(4) |
| | 60,000 | 6800 | - | 6520 | 6400(4) |
| | 90,000 | 6810 | 6720 | 6550 | 6610(1) |
| Average | | 6798 | 6790 | 6588 | 6260 |
| H-6, density, gm/cc 1.69 | Ground | 7190 | 7360 | 7340 | 6870 |
| | 30,000 | 7300(2) | 7430 | 7360 | 7980 |
| | 60,000 | 7280 | 7490 | 7550 | 7010 |
| | 90,000 | 7300(3) | 7270 | 7500 | 7000 |
| Average | | 7268 | 7385 | 7438 | 7215 |

*Confined charge in 1/4" steel tube, AISI 1015 seamless, 1" diameter 18" long, and 2" diameter 7" long. All means were determined from sets of five values unless otherwise indicated by ( ). A 26 gm tetryl booster was used to initiate each charge.

Average Fragment Velocities at Various Altitudes* (e)

| Explosive | Charge Diameter, Inches | Simulated Altitude, Feet | | | |
|---|---|---|---|---|---|
| | | Ground m/s | 30,000 m/s | 60,000 m/s | 90,000 m/s |
| TNT, density, gm/cc 1.51 | 1 | 2940 | 2991 | 3119 | 2868 |
| | 2 | 3623 | 4191 | 5077 | 4980 |
| H-6, density, gm/cc 1.71 | 1 | 3461 | 3405 | 3467 | 3563 |
| | 2 | 4603 | 4726 | 4998 | 5288 |

*Outside diameter 2.54"; inside diameter 2.04"; length 7".

References:

See HBX-1; HBX-3 reference list.

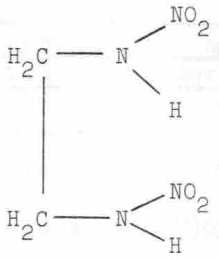
# Haleite (Ethylene Dinitramine) (EDNA)

(In recognition of its development as a military explosive by the late Dr. G. C. Hale of Picatinny Arsenal.)

**Composition:**

| | % |
|---|---|
| C | 16.0 |
| H | 4.0 |
| N | 37.3 |
| O | 42.7 |

C/H Ratio 0.066



**Molecular Weight:** $(C_2H_6N_4O_4)$ 150

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -32 |
| CO % | -10.5 |

**Density:** gm/cc — Crystal: 1.71

**Melting Point:** °C — Decomposes: 175+

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 48 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 14 |
| Sample Wt, mg | 17 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | Unaffected |

**Vacuum Stability Test:**

| cc/40 Hrs, at | |
|---|---|
| 90°C | |
| 100°C | 0.5 |
| 120°C | 1.5 |
| 135°C | -- |
| 150°C | 11+ |

**Rifle Bullet Impact Test:**

| | Trials | % |
|---|---|---|
| Explosions | 0 | |
| Partials | 60 | |
| Burned | 20 | |
| Unaffected | 20 | |

**200 Gram Bomb Sand Test:**

| | |
|---|---|
| Sand, gm | 52.3 |

**Explosion Temperature:**

| Seconds, 0.1 (no cap used) | °C |
|---|---|
| 1 | 265 |
| 5 Decomposes | 216 |
| 10 | 189 |
| 15 | 178 |
| 20 | 173 |
| | 170 |

**Sensitivity to Initiation:**

Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | 0.21 |
| Lead Azide | 0.13 |
| Tetryl | -- |

**Ballistic Mortar, % TNT:** (a) 139

**Trauzl Test, % TNT:** (b) 122

**75°C International Heat Test:**

| | |
|---|---|
| % Loss in 48 Hrs | 0.01 |

**Plate Dent Test:** (c)

| | |
|---|---|
| Method | A |
| Condition | Pressed |
| Confined | Yes |
| Density, gm/cc | 1.50 |
| Brisance, % TNT | 122 |

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.2 |
| % Loss, 2nd 48 Hrs | 0.3 |
| Explosion in 100 Hrs | None |

**Detonation Rate:**

| | |
|---|---|
| Confinement | Unconfined |
| Condition | Pressed |
| Charge Diameter, in. | 1.0 |
| Density, gm/cc | 1.49 |
| Rate, meters/second | 7570 |

**Flammability Index:** 138

**Hygroscopicity:** % 0.01

**Volatility:** Nil

Haleite (Ethylene Dinitramine) (EDNA)

**Booster Sensitivity Test:**

| | (d) |
|---|---|
| Condition | Pressed |
| Tetryl, gm | 100 |
| Wax, in. for 50% Detonation | 2.09 |
| Wax, gm | |
| Density, gm/cc | 1.42 |

**Heat of:**

| | |
|---|---|
| Combustion, cal/gm | 2477 |
| Explosion, cal/gm | 1276 |
| Gas Volume, cc/gm | 908 |
| Formation, cal/gm | 134 |
| Fusion, cal/gm | |

**Specific Heat:** cal/gm/°C

**Burning Rate:**
cm/sec

**Thermal Conductivity:**
cal/sec/cm/°C

**Coefficient of Expansion:**
Linear, %/°C

Volume, %/°C

**Hardness, Mohs' Scale:**

**Young's Modulus:**
E', dynes/cm²
E, lb/inch²
Density, gm/cc

**Compressive Strength:** lb/inch²

**Vapor Pressure:**

| °C | mm Mercury |
|---|---|

**Decomposition Equation:**

| | (e) | (e) | (f) |
|---|---|---|---|
| Oxygen, atoms/sec (Z/sec) | $10^{12.8}$ | $10^{12.1}$ | $10^{11.1}$ |
| Heat, kilocalorie/mole (ΔH, kcal/mol) | 30.5 | 37.3 | 30.8 |
| Temperature Range, °C | 184-254 | -- | 144-164 |
| Phase | Liquid | Solid | Solid |

**Armor Plate Impact Test:**

**60 mm Mortar Projectile:**
50% Inert, Velocity, ft/sec
Aluminum Fineness

**500-lb General Purpose Bombs:**

Plate Thickness, inches

1
1¼
1½
1¾

**Bomb Drop Test:**

**T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:**

Max Safe Drop, ft

**500-lb General Purpose Bomb vs Concrete:**

Height, ft
Trials
Unaffected
Low Order
High Order

**1000-lb General Purpose Bomb vs Concrete:**

Height, ft
Trials
Unaffected
Low Order
High Order

# Haleite (Ethylene Dinitramine) (EDNA)

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

| | |
|---|---|
| Density, gm/cc | 1.61 |
| Charge Wt, lb | -- |

**Total No. of Fragments:**

| | |
|---|---|
| For TNT | |
| For Subject HE | |

**3 inch HE, M42A1 Projectile, Lot KC-5:** 95/5 Haleite/wax

| | |
|---|---|
| Density, gm/cc | 1.56 |
| Charge Wt, lb | -- |

**Total No. of Fragments:**

| | |
|---|---|
| For TNT | 514 |
| For Subject HE | 600 |

**Fragment Velocity:** ft/sec

| | |
|---|---|
| At 9 ft | |
| At 25½ ft | |
| Density, gm/cc | |

**Blast (Relative to TNT):**

**Air:**
- Peak Pressure
- Impulse
- Energy

**Air, Confined:**
- Impulse

**Under Water:**
- Peak Pressure
- Impulse
- Energy

**Underground:**
- Peak Pressure
- Impulse
- Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** White

**Principal Uses:** Booster

**Method of Loading:** Pressed

**Loading Density:** gm/cc

| psi x $10^3$ | | | | |
|---|---|---|---|---|
| 5 | 10 | 12 | 15 | 20 |
| 1.28 | 1.38 | 1.41 | 1.44 | 1.49 |

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | |
| Exudation | None |

Compatibility with Metals:

Dry - Copper, brass, aluminum, mild steel, stainless steel, mild steel coated with acid-proof black paint, and mild steel plated with copper nickel, cadmium or zinc are unaffected. Magnesium and magnesium-aluminum alloy are slightly affected.

Wet - Copper, brass, mild steel coated with acid-proof black paint, and mild steel plated with copper, cadmium, nickel or zinc are heavily corroded. Aluminum is slightly affected and stainless steel is unaffected.

Impact Sensitivities of Various Crystal Habits:

Bureau of Mines Impact Test, 2 Kg Wt:

| Habit | cm |
|---|---|
| 1st plate | 55 |
| 2nd plate | 55 |
| Bi-pyramid | 71 |
| Bracydome | 66 |
| Sphenoid | 46 |

Solubility: gm/100 gm (%) of:

| Water | | Alcohol | |
|---|---|---|---|
| °C | % | °C | % |
| 20 | 0.25 | 20 | 1.00 |
| 40 | 0.75 | 40 | 2.46 |
| 60 | 2.13 | 60 | 5.29 |
| 80 | 6.38 | 78 | 10.4 |
| 100 | >20 | | |

Preparation:

(Summary Technical Report of the NDRC, Div 8, Vol 1)

$$CH_2O + HCN \rightarrow HO\ CH_2CN$$

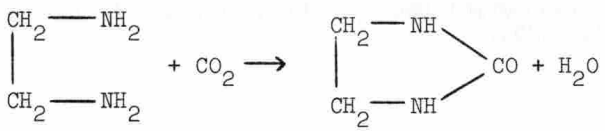
(98% yield)

$$HO\ CH_2CN + NH_3 \rightarrow NH_2CH_2CN + H_2O$$

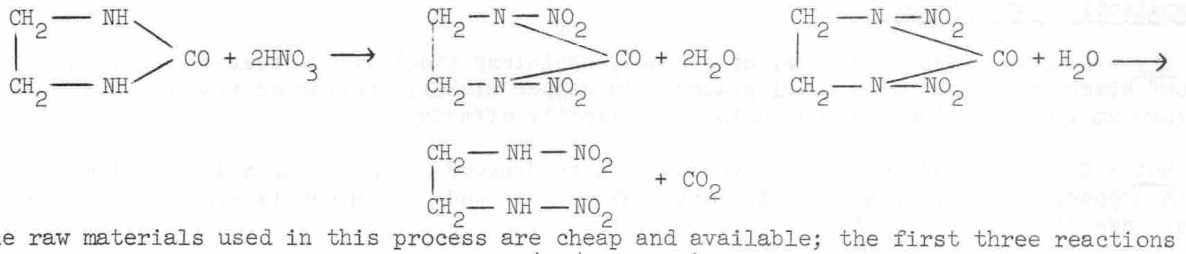
(82% yield)

$$NH_2CH_2CN + 2H_2 \rightarrow H_2N\ CH_2CH_2NH_2$$

(88% yield)



## Haleite (Ethylene Dinitramine) (EDNA)



The raw materials used in this process are cheap and available; the first three reactions proceed smoothly, rapidly and in good yield (70% overall), and only the third requires high pressures. The reaction of ethylenediamine with carbon dioxide at about 220°C and 820 atmospheres has been worked out and is more satisfactory for the preparation of ethyleneurea than the use of chlorethyl carbonate or urea and better than the reaction of acetic anhydride and ethylenediamine to yield N,N′-diacetyl-ethylenediamine which can be treated in a way similar to the above to yield Haleite.

Ethyleneurea is very easily nitrated, with strong nitric acid (98%), at ordinary temperature, and in a very short time, and the dinitroethyleneurea produced appears to hydrolyze, yielding Haleite, immediately after solution in water at 95°C. Both the nitration and hydrolysis are practically quantitative.

Origin:

First described in 1877 by Franchimont and Klobbie (Rec trav chim 7, 17 and 244) but it was 1935 before its value as an explosive was recognized. Standardized during World War II as a military explosive.

Destruction by Chemical Decomposition:

Haleite is decomposed by addition to hot, dilute sulfuric acid. Nitrous oxide, acetaldehyde and ethylene glycol are evolved. Haleite is also decomposed by addition to 5 times its weight of 20% sodium hydroxide.

References:[33]

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) Report AC-2983/Org Ex 179.

(c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(d) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

(e) R. J. Finkelstein and G. Gamow, Theory of the Detonation Process, NAVORD Report No. 90-46, 20 April 1947.

(f) M. A. Cook and M. Taylor Abbeg, "Isothermal Decomposition of Explosives," University of Utah, Ind Eng Chem (June 1956) pp. 1090-1095.

[33] See footnote 1, page 10.

(g) Also see the following Picatinny Arsenal Technical Reports on Haleite:

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1200 | 1231 | 1162 | 1113 | 414 | 1255 | 786 | 897 | 1198 | 1279 |
| 1290 | 1451 | 1232 | 1493 | 1294 | 1325 | 1796 | 1737 | 1288 | 1319 |
| 1360 | 1651 | 1252 | 1923 | 1434 | 1395 | | 1797 | 1378 | 1379 |
| 1380 | | 1352 | | | 1885 | | 1937 | 1388 | 1469 |
| 1400 | | 1372 | | | | | | 1838 | 1489 |
| 1600 | | | | | | | | | 2179 |

HBX-1

**Composition:**

| | % |
|---|---|
| RDX | 40 |
| TNT | 38 |
| Aluminum | 17 |
| D-2 Wax | 5 |
| Calcium Chloride, added | 0.5 |
| C/H Ratio | |

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | -- |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 16 |
| Sample Wt, mg | 21 |

**Friction Pendulum Test:** (b)

| | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | --- |

**Rifle Bullet Impact Test:** Trials (b)

| | % |
|---|---|
| Explosions | 73 |
| Partials | -- |
| Burned | -- |
| Unaffected | 28 |

**Explosion Temperature:** °C (a)

| Seconds, 0.1 (no cap used) | --- |
|---|---|
| 1 | --- |
| 5 | 480 |
| 10 | |
| 15 | |
| 20 | |

**75°C International Heat Test:**
% Loss in 48 Hrs

**100°C Heat Test:** (b)

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.058 |
| % Loss, 2nd 48 Hrs | 0.00 |
| Explosion in 100 Hrs | None |

**Flammability Index:**

**Hygroscopicity:** % 30°C, 95% RH, 7 days 2.98
71°C, 95% RH, 7 days 1.13

**Volatility:**

**Molecular Weight:** 102

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -68 |
| CO % | -35 |

**Density:** gm/cc Cast 1.72

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$
$n_{25}^{D}$
$n_{30}^{D}$

**Vacuum Stability Test:** (a, b)
cc/40 Hrs, at

| | |
|---|---|
| 90°C | ---- |
| 100°C | 0.47 |
| 120°C | 0.98 |
| 135°C | ---- |
| 150°C | 11+ |

**200 Gram Bomb Sand Test:**
Sand, gm 48.1

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | ---- |
| Lead Azide | 0.20 |
| Tetryl | 0.10 |

**Ballistic Mortar, % TNT:** (d) 133

**Trauzl Test, % TNT:**

**Plate Dent Test:**
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**Detonation Rate:** (a, b)

| | |
|---|---|
| Confinement | None |
| Condition | Cast |
| Charge Diameter, in. | 1.0 |
| Density, gm/cc | 1.69 |
| Rate, meters/second | 7224 |

**Booster Sensitivity Test:** (c)

| | |
|---|---|
| Condition | Cast |
| Tetryl, gm | 100 |
| Wax, in. for 50% Detonation | 1.25 |
| Wax, gm | |
| Density, gm/cc | 1.73 |

**Heat of:** (b)

| | |
|---|---|
| Combustion, cal/gm | 3882 |
| Explosion, cal/gm | 919 |
| Gas Volume, cc/gm | |
| Formation, cal/gm | 758 |
| Fusion, cal/gm 78°C | 9.25 |

**Specific Heat:** cal/gm/°C (b)

| | |
|---|---|
| 30°C | 0.249 |
| 50°C | 0.264 |

**Burning Rate:**
cm/sec

**Thermal Conductivity:** (b)
cal/sec/cm/°C 35°C $0.97 \times 10^{-3}$

**Coefficient of Expansion:** (b)
Linear, $\Delta\ell$/inch

| | |
|---|---|
| 0°C | $46 \times 10^{-4}$ |
| 35°C | $95 \times 10^{-4}$ |
| 70°C | $159 \times 10^{-4}$ |

**Hardness, Mohs' Scale:**

**Young's Modulus:** (b)

| | |
|---|---|
| E', dynes/cm² | $10.3 \times 10^{9}$ |
| E, lb/inch² | $1.49 \times 10^{-5}$ |
| Density, gm/cc | 1.69 |

**Compressive Strength:** lb/inch² See below

**Vapor Pressure:**

| °C | mm Mercury |
|---|---|

(b)

Compressive Strength: lb/inch²

| | |
|---|---|
| Density, gm/cc | 1303 |
| Ultimate deformation, % | 1.69 |
| | 1.38 |

**Decomposition Equation:**

| | |
|---|---|
| Oxygen, atoms/sec (Z/sec) | |
| Heat, kilocalorie/mole (ΔH, kcal/mol) | |
| Temperature Range, °C | |
| Phase | |

**Armor Plate Impact Test:**

**60 mm Mortar Projectile:**

| | |
|---|---|
| 50% Inert, Velocity, ft/sec | |
| Aluminum Fineness | |

**500-lb General Purpose Bombs:**

Plate Thickness, inches

| | |
|---|---|
| 1 | |
| 1¼ | |
| 1½ | |
| 1¾ | |

**Bomb Drop Test:**

**T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:**

Max Safe Drop, ft

**500-lb General Purpose Bomb vs Concrete:**

| | |
|---|---|
| Height, ft | |
| Trials | |
| Unaffected | |
| Low Order | |
| High Order | |

**1000-lb General Purpose Bomb vs Concrete:**

| | |
|---|---|
| Height, ft | |
| Trials | |
| Unaffected | |
| Low Order | |
| High Order | |

**Fragmentation Test:** (b)

**90 mm HE, M71 Projectile, Lot** EGS-1-17:

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

| | |
|---|---|
| For Composition B | 998 |
| For Subject HE | 910 |
| For 80/20 Tritonal | 616 |

**3 inch HE, M42A1 Projectile, Lot KC-5:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**Fragment Velocity:** ft/sec

At 9 ft

At 25½ ft

Density, gm/cc

**Blast (Relative to TNT):** (a)

**Air:** 3.25" diameter sphere

| | | |
|---|---|---|
| Peak Pressure Δ | psi Catenary | 24.7 |
| | NFOC Pendulum | 19.6 |
| Impulse | | |
| Energy | | ---- |

**Air, Confined:**

Impulse

**Under Water:**

Peak Pressure

Impulse

Energy

**Underground:**

Peak Pressure

Impulse

Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Gray

**Principal Uses:** HE charge

**Method of Loading:** Cast

**Loading Density:** gm/cc 1.69

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | None |

**Composition:**

| | % |
|---|---|
| RDX | 31 |
| TNT | 29 |
| Aluminum | 35 |
| D-2 Wax | 5 |
| Calcium Chloride, added | 0.5 |
| C/H Ratio | |

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | -- |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 15 |
| Sample Wt, mg | 23 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | --- |

**Rifle Bullet Impact Test:** Trials (b)

| | % |
|---|---|
| Explosions | 78 |
| Partials | -- |
| Burned | -- |
| Unaffected | 22 |

**Explosion Temperature:** °C (a)

| | |
|---|---|
| Seconds, 0.1 (no cap used) | --- |
| 1 | --- |
| 5 | 500 |
| 10 | |
| 15 | |
| 20 | |

**75°C International Heat Test:**
% Loss in 48 Hrs

**100°C Heat Test:** (b)

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.70 |
| % Loss, 2nd 48 Hrs | 0.00 |
| Explosion in 100 Hrs | None |

**Flammability Index:**

**Hygroscopicity:** % (b)

| | |
|---|---|
| 30°C, 95% RH, 7 days | 2.01 |
| 71°C, 95% RH, 7 days | 0.31 |

**Volatility:**

**Molecular Weight:** 64

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -75 |
| CO % | -49 |

**Density:** gm/cc Cast 1.84

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Vacuum Stability Test:** (a, b)
cc/40 Hrs, at

| | |
|---|---|
| 90°C | ---- |
| 100°C | 0.45 |
| 120°C | |
| 135°C | |
| 150°C | |

**200 Gram Bomb Sand Test:** (b)

| | |
|---|---|
| Sand, gm | 44.9 |

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | ---- |
| Lead Azide | 0.20 |
| Tetryl | 0.10 |

**Ballistic Mortar, % TNT:** (d) 111

**Trauzl Test, % TNT:**

**Plate Dent Test:**

| | |
|---|---|
| Method | |
| Condition | |
| Confined | |
| Density, gm/cc | |
| Brisance, % TNT | |

**Detonation Rate:** (a, b)

| | |
|---|---|
| Confinement | None |
| Condition | Cast |
| Charge Diameter, in. | 1.0 |
| Density, gm/cc | 1.81 |
| Rate, meters/second | 6917 |

**Booster Sensitivity Test:**
- Condition
- Tetryl, gm
- Wax, in. for 50% Detonation
- Wax, gm
- Density, gm/cc

**Heat of:** (b)
- Combustion, cal/gm — 4495
- Explosion, cal/gm — 877
- Gas Volume, cc/gm
- Formation, cal/gm — 491
- Fusion, cal/gm — 9.30

**Specific Heat:** cal/gm/°C
- 30°C — 0.254
- 50°C — 0.254

**Burning Rate:**
cm/sec

**Thermal Conductivity:** (b)
cal/sec/cm/°C 35°C — $1.70 \times 10^{-3}$

**Coefficient of Expansion:** (b)
Linear, $\Delta \ell$/inch
- 0°C — $40 \times 10^{-4}$
- 35°C — $83 \times 10^{-4}$
- 70°C — $130 \times 10^{-4}$

**Hardness, Mohs' Scale:**

**Young's Modulus:** (b)
- E', dynes/cm² — $11.5 \times 10^{9}$
- E, lb/inch² — $1.67 \times 10^{5}$
- Density, gm/cc — 1.81

**Compressive Strength:** lb/inch² — See below

**Vapor Pressure:**
°C mm Mercury

Compressive Strength: lb/inch² — 1610
- Density, gm/cc — 1.81
- Ultimate deformation, % — 1.37

**Decomposition Equation:**
- Oxygen, atoms/sec (Z/sec)
- Heat, kilocalorie/mole (ΔH, kcal/mol)
- Temperature Range, °C
- Phase

**Armor Plate Impact Test:**

**60 mm Mortar Projectile:**
- 50% Inert, Velocity, ft/sec
- Aluminum Fineness

**500-lb General Purpose Bombs:**

Plate Thickness, inches
- 1
- 1¼
- 1½
- 1¾

**Bomb Drop Test:**

**T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:**

Max Safe Drop, ft

**500-lb General Purpose Bomb vs Concrete:**
- Height, ft
- Trials
- Unaffected
- Low Order
- High Order

**1000-lb General Purpose Bomb vs Concrete:**
- Height, ft
- Trials
- Unaffected
- Low Order
- High Order

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot** EGS-1-17:

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For Composition B 998

For Subject HE 476

For 80/20 Tritonal 616

**3 inch HE, M42A1 Projectile, Lot KC-5:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**Fragment Velocity:** ft/sec

At 9 ft

At 25½ ft

Density, gm/cc

**Blast (Relative to TNT):** (a)

**Air:** 3.25" diameter sphere

Peak Pressure Δ psi Catenary 25.5

NFOC Pendulum 20.6

Impulse

Energy ----

**Air, Confined:**

Impulse

**Under Water:**

Peak Pressure

Impulse

Energy

**Underground:**

Peak Pressure

Impulse

Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Gray

**Principal Uses:** HE charge

**Method of Loading:** Cast

**Loading Density:** gm/cc 1.81

**Storage:**

Method Dry

Hazard Class (Quantity-Distance) Class 9

Compatibility Group Group I

Exudation None

The Stability of HBX Compositions Made With and Without Desiccants and Containing Added Moisture *

| Explosive Composition | Moisture, % | Acidity, % | 100°C Vac Stab Test cc gas | 100°C Vac Stab Test Hours | Hygroscopicity, % 95% RH 30°C | Hygroscopicity, % 95% RH 71°C |
|---|---|---|---|---|---|---|
| Standard HBX-1 | 0.73 | 0.011 | 0.47 | 40 | +2.98 | +1.13 |
| +0.2% moisture | | | 0.68 | 40 | | |
| +0.4% moisture | | | 0.62 | 40 | | |
| +0.6% moisture | | | 0.50 | 40 | | |
| HBX-1 without $CaCl_2$ | 0.00 | 0.029 | 0.36 | 40 | -0.06 | -0.25 |
| +0.2% moisture | | | 0.25 | 40 | | |
| +0.4% moisture | | | 0.23 | 40 | | |
| +0.6% moisture | | | 0.27 | 40 | | |
| HBX-1 with silica gel | 0.06 | 0.031 | 0.73 | 40 | +0.08 | +0.04 |
| Standard HBX-3 | 0.54 | 0.012 | 0.45 | 40 | +2.01 | +0.31 |
| +0.2% moisture | | | 0.47 | 40 | | |
| +0.4% moisture | | | 0.43 | 40 | | |
| +0.6% moisture | | | 0.41 | 40 | | |
| HBX-3 without $CaCl_2$ | 0.02 | 0.049 | 0.46 | 40 | -0.06 | -0.29 |
| +0.2% moisture | | | 0.26 | 40 | | |
| +0.4% moisture | | | 0.26 | 40 | | |
| +0.6% moisture | | | 0.20 | 40 | | |
| HBX-3 with silica gel | 0.04 | 0.100 | 0.45 | 40 | +0.09 | +0.05 |
| Standard H-6 | 0.71 | 0.017 | 0.47 | 40 | +2.01 | +1.77 |
| +0.2% moisture | | | 0.88 | 40 | | |
| +0.4% moisture | | | 0.63 | 40 | | |
| +0.6% moisture | | | 0.65 | 40 | | |
| H-6 without $CaCl_2$ | 0.03 | 0.082 | 0.40 | 40 | -0.06 | -0.25 |
| +0.2% moisture | | | 0.10 | 40 | | |
| +0.4% moisture | | | 0.25 | 40 | | |
| +0.6% moisture | | | 0.23 | 40 | | |
| H-6 with silica gel | 0.05 | 0.028 | 0.43 | 40 | +0.09 | +0.06 |

* All samples were ground to 20/100 mesh size, 7 days before tests. Silica gel used was Fisher Scientific Company, Lot 541492, through 100 mesh U. S. Standard Sieve.

Preparation:

HBX explosive mixtures are prepared by melting TNT in a steam-jacketed melt kettle equipped with a mechanical stirrer. Water-wet RDX is added slowly with stirring and heating until all the water is evaporated. Aluminum is added, and the composition is stirred until uniform. D-2 wax and calcium chloride are then added. The desensitizer wax, also known as Composition D-2, consists of 84% paraffin and other waxes, 14% nitrocellulose and 2% lecithin. The mixture is cooled from approximately 95° to 100°C to a temperature considered suitable for casting (the lowest practicable pour temperature). HBX can also be made by adding the calculated amount of TNT to Composition B to obtain the desired proportion of RDX/TNT. The appropriate weights of the other ingredients are added to complete the mixture.

Origin:

Developed during World War II, as relatively insensitive mixtures, by adding 5% desensitizer to Torpex II, for high blast explosive applications.

References:[34]

(a) O. E. Sheffield, Blast Properties of Explosives Containing Aluminum or Other Metal Additives, PATR No. 2353, November 1956.

(b) S. D. Stein, G. J. Horvat and O. E. Sheffield, Some Properties and Characteristics of HBX-1, HBX-3 and H-6, PATR No. 2431, June 1957.

(c) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo. 10,303, 15 June 1949.

(d) S. R. Walton, Report on the Program to Develop an Improved HBX-Type Explosive, NAVORD Report No. 1502, 26 July 1950.

(e) A. W. O'Brien, Jr., C. W. Plummer, R. P. Woodburn and V. Philipchuk, Detonation Velocity Determinations and Fragment Velocity Determinations of Varied Explosive Systems and Conditions, National Northern Corporation Final Summary Report NNC-F-13, February 1958 (Contract DAI-19-020-501-ORD-(P)-58).

(f) Also see the following Picatinny Arsenal Technical Reports on HBX Explosives: 1756, 2138, 2169.

[34]See footnote 1, page 10.

**Composition:**

| | % |
|---|---|
| Potassium Perchlorate (17 microns) | 32 |
| Aluminum, atomized (20 microns) | 48 |
| RDX (through 325 mesh) | 16 |
| Asphaltum (through 100 mesh) | 4 |
| C/H Ratio | |

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | -- |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 16 |
| Sample Wt, mg | 24 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Detonates |
| Fiber Shoe | Unaffected |

**Rifle Bullet Impact Test:**

| | Trials | % |
|---|---|---|
| Explosions | | |
| Partials | | |
| Burned | | |
| Unaffected | | |

**Explosion Temperature:** °C

| Seconds, 0.1 (no cap used) | --- |
|---|---|
| 1 | --- |
| 5 | 520 |
| 10 | |
| 15 | |
| 20 | |

**75°C International Heat Test:**
% Loss in 48 Hrs

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.15 |
| % Loss, 2nd 48 Hrs | 0.00 |
| Explosion in 100 Hrs | None |

**Flammability Index:**

**Hygroscopicity:** % None

**Volatility:** None

**Molecular Weight:** 47.6

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -42 |
| CO % | -34 |

**Density:** gm/cc

| | |
|---|---|
| Apparent | 1.39 |
| Pressed at 20,000 psi | 2.1 |

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Vacuum Stability Test:**

| cc/40 Hrs, at | |
|---|---|
| 90°C | ---- |
| 100°C | 1.25 |
| 120°C | |
| 135°C | |
| 150°C | |

**200 Gram Bomb Sand Test:**

| | |
|---|---|
| Sand, gm | 12.5 |

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | ---- |
| Lead Azide | 0.20 |
| Tetryl | 0.25 |

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**Plate Dent Test:**
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**Detonation Rate:**
Confinement
Condition
Charge Diameter, in.
Density, gm/cc
Rate, meters/second

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

| | |
|---|---|
| Flame Temperature, $^{o}K$ | 2552 |
| Activation Energy, kcal | 20.4 |
| Temp, $^{o}C$ | 450 to 570 |
| Specific reaction rate, k | $1.64 \times 10^{-5}$ |

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Gray

**Principal Uses:** HE filler for small caliber projectiles

**Method of Loading:** Pressed

**Loading Density:** gm/cc
Pressed at 20,000 psi: 2.1

**Storage:**

Method: Dry

Hazard Class (Quantity-Distance)

Compatibility Group

Exudation: None

Static Tests:
20 mm T215E1 Projectile:

| | |
|---|---|
| PA Peak Pressure, psi | 55 |
| NFOC 20" Blast Cube | 44 |
| APG 24" Blast Cube | 44 |

Static Tests:
20 mm M97 Projectile:

| | HEX-24 | Tritonal | Torpex |
|---|---|---|---|
| Foxboro psi | 19 | 12.4 | 13.0 |
| Catenary psi | 46 | ---- | ---- |
| Duration, microsec | 533 | ---- | ---- |
| APG 24" Blast Cube | 36 | 24 | 32 |

Heat of:

| | |
|---|---|
| Combustion, cal/gm | 4197 |
| Explosion, cal/gm | 1858 |
| Gas volume, cc/gm | 159 |

**Composition:**

| | % |
|---|---|
| Potassium Perchlorate (17 microns) | 32 |
| Aluminum, flaked (1 micron) | 48 |
| RDX (through 325 mesh) | 16 |
| Asphaltum (through 100 mesh) | 4 |

C/H Ratio

**Impact Sensitivity, 2 Kg Wt:**
Bureau of Mines Apparatus, cm
Sample Wt 20 mg
Picatinny Arsenal Apparatus, in.
Sample Wt, mg

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Partially detonates |
| Fiber Shoe | Unaffected |

**Rifle Bullet Impact Test:**

| | Trials | % |
|---|---|---|
| Explosions | | |
| Partials | | |
| Burned | | |
| Unaffected | | |

**Explosion Temperature:** °C

| Seconds, 0.1 (no cap used) | --- |
|---|---|
| 1 | --- |
| 5 | 545 |
| 10 | |
| 15 | |
| 20 | |

**75°C International Heat Test:**
% Loss in 48 Hrs

**100°C Heat Test:**
% Loss, 1st 48 Hrs
% Loss, 2nd 48 Hrs
Explosion in 100 Hrs

**Flammability Index:**

**Hygroscopicity:** %

**Volatility:**

**Molecular Weight:** 47.6

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -42 |
| CO % | -34 |

**Density:** gm/cc

| | |
|---|---|
| Apparent | 0.69 |
| Pressed at 20,000 psi | 1.62 |

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Vacuum Stability Test:**
cc/40 Hrs, at

| | |
|---|---|
| 90°C | ---- |
| 100°C | 1.52 |
| 120°C | |
| 135°C | |
| 150°C | |

**200 Gram Bomb Sand Test:**

| | |
|---|---|
| Sand, gm | 23.7 |

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | ---- |
| Lead Azide | 0.20 |
| Tetryl | 0.25 |

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**Plate Dent Test:**
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**Detonation Rate:**
Confinement
Condition
Charge Diameter, in.
Density, gm/cc
Rate, meters/second

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

| | |
|---|---|
| Flame Temperature, °K | 2382 |
| Activation Energy, kcal | 25.4 |
| Temp, °C | 450 to 470 |
| Specific reaction rate, k | $7.84 \times 10^{-6}$ |

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Gray

**Principal Uses:** HE filler for small caliber projectiles

**Method of Loading:** Pressed

**Loading Density:** gm/cc
Pressed at 20,000 psi 1.62

**Storage:**
Method: Dry
Hazard Class (Quantity-Distance)
Compatibility Group
Exudation: None

Static Tests:
20 mm T215E1 Projectile:

| | |
|---|---|
| PA Peak Pressure, psi | 77 |
| NFOC 20" Blast Cube | 45 |
| APG 24" Blast Cube | 42 |

Static Tests:
20 mm M97 Projectile:

| | HEX-48 | TNT | Tetryl |
|---|---|---|---|
| Fosboro psi | 17.3 | 2.8 | 3.5 |
| Catenary psi | 43 | 28 | 28 |
| Duration, microsec | 517 | 560 | 530 |
| APG 24" Blast Cube | 29 | --- | 10 |

Heat of:

| | |
|---|---|
| Combustion, cal/gm | 4119 |
| Explosion, cal/gm | 1735 |
| Gas Volume, cc/gm | 200 |

Cook-Off Tests: (c)

20 mm T215E1 HEX-48 Loaded Projectiles With Dye-Coated RDX Top-Off

| Projectile No. | Cut-Off Temp. °C | Cook-Off |
|---|---|---|
| 1 | 170 | Yes (198) |
| 2 | 150 | No |
| 3 | 155 | Yes (190) |
| 4 | 150 to 175 | No |

National Northern Projectile Load:

| | |
|---|---|
| MOX-2B (no top-off) | 195 |
| MOX-2B (Tetryl top-off) | 150 |
| MOX-2B (97/3, RDX/wax top-off) | 175 |
| MOX-2 (no top-off) | 175 |

Fragment Penetration Tests: (c)

| Projectile | Filler | Altitude, Feet | Avg. No. of Penetrations per Round in Zone 65°-130° | | |
|---|---|---|---|---|---|
| | | | 0.020" | 0.040" | 0.051" |
| T215E1 | HEX-48 | Ground | 352 | 264 | 282 |
| | | 60,000 | 676 | 432 | 388 |
| T282E1 | MOX-2B | Ground | 634 | 290 | 235 |
| | | 60,000 | 807 | 367 | 250 |
| EX8 Mod 0 | MOX-2B | Ground | 476 | 268 | 224 |
| | | 60,000 | 672 | 264 | 256 |

The fragment penetration test records numbers of complete penetrations of aluminum panels of various thicknesses at 2.5 feet from the static detonation. The total penetrations recorded on the 24ST-3 aluminum panels occurred with the projectile nose always pointed toward 0° and the base toward 180°.

The test data indicate that on the thicker panels, 0.040" and 0.051," the HEX-48 loaded T215E1 projectile produced more complete fragment penetrations at ground and altitude than MOX-2B loaded T282E1 and EX8 Mod 0 projectiles.

Preparation:

The HEX compositions were prepared by blending the appropriate weight of the dry ingredients in a Patterson-Kelly twin-shell blender for at least 30 minutes.

An alternate procedure for 100 to 200 gram batches used a "Cradle-Roll" mixing device. This device consisted of a half-barrel type container constructed of wood and lined with an electrical conductive material. A plastic roll was allowed to move over the ingredients by remote control action of the container. The roll action prevented caking of the mix but had no adverse effect on the particle size of the ingredients. The period of time required to obtained a uniform and intimate mixture was approximately fifteen minutes.

Origin:

The development of "slow-burning" explosive mixtures which would produce increased blast effects in enclosed or nearly enclosed spaces directed attention to their use for possible military application. In 1950 Picatinny Arsenal developed a high capacity filler for 20mm projectiles consisting of 85/10/5 RDX/aluminum/desensitizer which was more powerful than standard tetryl filler. However, in comparison with MOX type explosives, there was little doubt as to the superior performance of the MOX mixture. HEX (high energy explosive) mixtures were developed at Picatinny Arsenal in 1953 (Ref a) as superior high blast compositions suitable for use in small caliber projectiles.

References:[35]

(a) O. E. Sheffield and E. J. Murray, Development of Explosives—Metallized Explosives—High Blast Fillers for Small Caliber Shell, Picatinny Arsenal Memorandum Report No. MR-49, 21 December 1953.

(b) O. E. Sheffield, Properties of MOX-Type Explosive Mixtures, PATR No. 2205, October 1955.

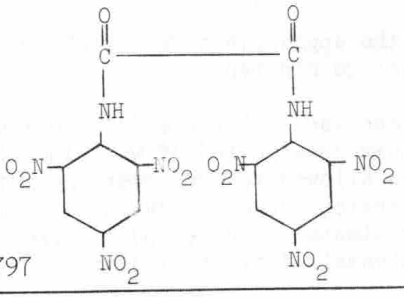
(c) National Northern Corporation, Letter from Dr. C. M. Saffer, Jr., to Commanding Officer, Picatinny Arsenal, 12 June 1957.

[35]See footnote 1, page 10.

# 2,4,6,2',4',6'-Hexanitro-oxanilide (HNO)

**Composition:**

| | % |
|---|---|
| C | 33.0 |
| H | 1.2 |
| N | 21.9 |
| O | 43.9 |
| C/H Ratio | 0.797 |



**Molecular Weight:** ($C_{14}H_6N_8O_{14}$)

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -53.4 |
| CO % | - 9.4 |

**Density:** gm/cc

**Melting Point:** °C Decomposes 302

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | -- |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 15 |
| Sample Wt, mg | 12 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | Unaffected |

**Vacuum Stability Test:**

cc/40 Hrs, at

| | |
|---|---|
| 90°C | |
| 100°C | 0.40 |
| 120°C | |
| 135°C | |
| 150°C | |

**Rifle Bullet Impact Test:**

| | Trials | % |
|---|---|---|
| Explosions | | |
| Partials | | |
| Burned | | |
| Unaffected | | |

**200 Gram Bomb Sand Test:**

| | |
|---|---|
| Sand, gm | 52.1 |

**Explosion Temperature:** °C

| Seconds, 0.1 (no cap used) | -- |
|---|---|
| 1 | -- |
| 5 | 384 |
| 10 | |
| 15 | |
| 20 | |

**Sensitivity to Initiation:**

Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | -- |
| Lead Azide | 0.30 |
| Tetryl | 0.25 |

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**75°C International Heat Test:**

% Loss in 48 Hrs

**Plate Dent Test:**

Method

Condition

Confined

Density, gm/cc

Brisance, % TNT

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.07 |
| % Loss, 2nd 48 Hrs | 0.05 |
| Explosion in 100 Hrs | None |

**Detonation Rate:**

Confinement

Condition

Charge Diameter, in.

Density, gm/cc

Rate, meters/second

**Flammability Index:**

**Hygroscopicity:** % 25°C, 90% RH 0.19

**Volatility:**

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Almost white

**Principal Uses:** Igniter powder; pyrotechnic compositions

**Method of Loading:** Pressed and extruded

**Loading Density:** gm/cc

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | |
| Exudation | None |

Solubility in the following substances:

| Solvent | |
|---|---|
| Nitrobenzene | <3 gm in 100 cc, at 23°C ~ 5 gm in 100 cc, at 210°C |
| Water | 0.10 gm in 100 cc, at 100°C |
| Alcohol (Ethyl) | Insoluble |
| Acetone | Insoluble |
| Benzene | Insoluble |
| Butyl acetate | Insoluble |
| Carbon tetrachloride | Insoluble |
| Dimethylformamide | Very soluble |
| Ether (Ethyl) | Insoluble |
| Acetic Acid | Insoluble |
| Nitric Acid | Soluble |
| Crystalline form | Long rectangular glistening plates from nitrobenzene |

Preparation:

To prepare hexanitro-oxanilide, first prepare tetranitro-oxanilide as described herein under the entry "2,4,2',4'-Tetranitro-oxanilide (TNO)."

A 1.5 liter round bottom flask is equipped with a stirrer of the type which causes a downward swirl. The flask is jacketed for hot and cold water. 187 grams of nitric acid of specific gravity 1.49 (commercial grade) is placed into the flask and 100 grams of sulphuric acid is added to the nitric acid under agitation. The mixed acid is cooled to 10°C. 29.2 grams of tetranitro-oxanilide is slowly added to the mixed acid under rapid agitation maintaining the temperature at 8°-10°C. After the addition of the TNO is completed (approximately 25 minutes) the temperature is raised to 85°C over a period of 2 hours and held at 85°-90°C for one hour. The hexanitro-oxanilide (HNO) "slurry" is filtered on a Büchner funnel and purified as explained under "Tetranitro-oxanilide."

Origin:

A. G. Perkin in 1892 obtained hexanitro-oxanilide directly by heating to boiling a solution of tetranitro-oxanilide in a mixture of sulfuric and nitric acids. He also prepared the same compound from oxanilide by the action of a boiling mixture of fuming nitric and sulfuric acids (J Chem Soc 61, 462 (1892)).

References:[36]

(a) L. Gowen and R. Dwiggens, Case Gun Ignition Studies, NAVORD Report No. 2321, 13 June 1952.

(b) D. Dubrow and J. Kristal, Substitution of Tetranitro Oxanilide and Hexanitro Oxanilide for Tetranitro Carbazole, PA Pyrotechnic Research Laboratory Report 54-TF1-88, 20 December 1954.

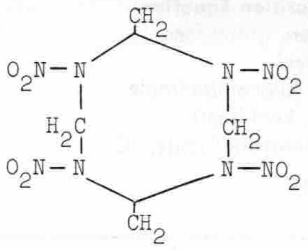
(c) S. Livingston, Preparation of Tetranitro Carbazole, PA Chemical Research Laboratory Report 136,330, 11 April 1951.

(d) S. Livingston, Development of Improved Ignition Type Powders, PATR No. 2267, July 1956.

[36]See footnote 1, page 10.

**Composition:**

| | % |
|---|---|
| C | 16.2 |
| H | 2.7 |
| N | 37.9 |
| O | 43.2 |



C/H Ratio 0.095

**Molecular Weight:** ($C_4H_8N_8O_8$) 296

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -21.6 |
| CO % | 0.0 |

**Density:** gm/cc Crystal 1.90

**Melting Point:** °C Capillary method 273
Koffer Micro Hot Stage 280

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 32 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 9 |
| Sample Wt, mg | 23 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Explodes |
| Fiber Shoe | Unaffected |

**Vacuum Stability Test:**

| cc/40 Hrs, at | |
|---|---|
| 90°C | |
| 100°C | 0.37 |
| 120°C | 0.45 |
| 135°C | -- |
| 150°C | 0.62 |

**Rifle Bullet Impact Test:**

| | Trials | % |
|---|---|---|
| Explosions | | |
| Partials | | |
| Burned | | |
| Unaffected | | |

**200 Gram Bomb Sand Test:**

Sand, gm 60.4

**Explosion Temperature:**

| Seconds, 0.1 (no cap used) | °C 380 |
|---|---|
| 1 | -- |
| 5 | 327 |
| 10 | 306 |
| 15 | -- |
| 20 | -- |

**Sensitivity to Initiation:**

Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | |
| Lead Azide | 0.30 |
| Tetryl | |

**Ballistic Mortar, % TNT:** 150

**Trauzl Test, % TNT:** 145

**75°C International Heat Test:**
% Loss in 48 Hrs

**Plate Dent Test:**

| | |
|---|---|
| Method | |
| Condition | |
| Confined | |
| Density, gm/cc | |
| Brisance, % TNT | |

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.05 |
| % Loss, 2nd 48 Hrs | 0.03 |
| Explosion in 100 Hrs | None |

**Flammability Index:**

**Detonation Rate:**

| | |
|---|---|
| Confinement | |
| Condition | |
| Charge Diameter, in. | |
| Density, gm/cc | 1.84 |
| Rate, meters/second | 9124 |

**Hygroscopicity:** %
30°C, 95% RH (c) 0.00

**Volatility:**

**Booster Sensitivity Test:**
- Condition
- Tetryl, gm
- Wax, in. for 50% Detonation
- Wax, gm
- Density, gm/cc

**Heat of:**
- Combustion, cal/gm — 2362
- Explosion, cal/gm (e) — 1356
  - Gas Volume, cc/gm
- Formation, cal/gm (e) — -60.5
- Fusion, cal/gm

**Specific Heat:** cal/gm/°C

Recrystallized (g)

| °C | | °C | |
|---|---|---|---|
| -75 | 0.153 | 85 | 0.288 |
| 0 | 0.228 | 90 | 0.290 |
| 25 | 0.248 | 100 | 0.295 |
| 50 | 0.266 | 125 | 0.307 |
| 75 | 0.282 | 150 | 0.315 |

**Burning Rate:**
cm/sec

**Thermal Conductivity:**
cal/sec/cm/°C

**Coefficient of Expansion:**
- Linear, %/°C
- Volume, %/°C

**Hardness, Mohs' Scale:** (e) 2.3

**Young's Modulus:**
- E', dynes/cm²
- E, lb/inch²
- Density, gm/cc

**Compressive Strength:** lb/inch²

**Vapor Pressure:**

°C mm Mercury

**Decomposition Equation:** (e) $10^{19.7}$
- Oxygen, atoms/sec (Z/sec)
- Heat, kilocalorie/mole (ΔH, kcal/mol) — 52.7
- Temperature Range, °C — 271-314
- Phase — Liquid

**Armor Plate Impact Test:**

**60 mm Mortar Projectile:**
- 50% Inert, Velocity, ft/sec
- Aluminum Fineness

**500-lb General Purpose Bombs:**

Plate Thickness, inches

- 1
- 1¼
- 1½
- 1¾

**Bomb Drop Test:**

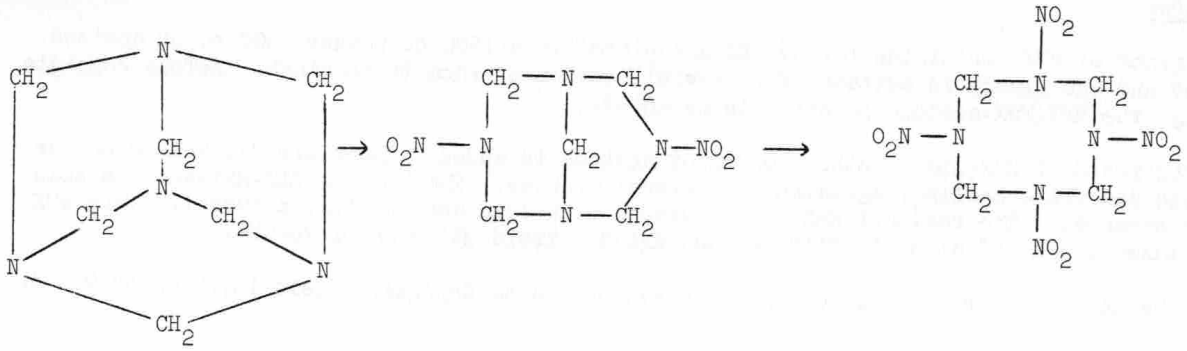
**T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:**

Max Safe Drop, ft

**500-lb General Purpose Bomb vs Concrete:**
- Height, ft
- Trials
- Unaffected
- Low Order
- High Order

**1000-lb General Purpose Bomb vs Concrete:**
- Height, ft
- Trials
- Unaffected
- Low Order
- High Order

Preparation: (b)



Two men are required to regulate the addition of reagents and control the temperature during the initial stage addition; one man can complete the procedure. A 1-liter 5-necked flask is used, the center neck for an efficient stirrer, one side neck for a thermometer, and the other necks for burrettes and a gas outlet (to water trap). The flask is placed in a pan with steam and cold water inlets, for temperature control.

Five cc of acetic anhydride and 250 cc glacial acetic acid are poured into the flask and the temperature brought to 45 ± 1°C, and held there for the duration of the entire reaction. The reagents (a solution of 33.6 gm hexamine in 55 gm of glacial acetic acid, 100 cc of acetic anhydride and 40 cc of a solution of 42.3/57.7-ammonium nitrate/98% nitric acid) are then added simultaneously, continuously and equivalently over a 25-minute period. The reaction mixture is aged 15 minutes.

The second stage reagents (60 cc of 42.3/57.7, ammonium nitrate/98% nitric acid and 150 cc acetic anhydride) are then added simultaneously, continuously and equivalently over a 25-minute period. The mixture is aged 65 minutes, poured into 1.5 liter of water and simmered on a steam bath for 12 hours. Cool, filter and dry the RDX-HMX precipitate (yield 73% HMX).

The RDX is destroyed, leaving HMX, as follows: 1025 gm of the crude product are placed in a solution of 15 gm sodium tetraborate decahydrate in 5 liters of water, heated to boiling with agitation, and 5 N NaOH added at the rate of 3 cc/min. When about 730 cc have been added the pH increases sharply from a little over 8.7 to over 9.7 which corresponds to complete destruction of the RDX. Filter the HMX from the hot mixture; yield 612 gm, mp 279.5°-280.5°C. Recrystallization from nitromethane yields material melting at 281°-282°C.

Origin:

Was discovered as an impurity (by-product) in the nitration of hexamethylene-tetramine to form RDX. It is now manufactured directly by the process described above and has valuable use in explosive systems.

Removal of RDX from HMX-RDX Mixtures and Recovery of a RDX-HMX Mixture (This procedure appears suitable for use with mixtures containing 80% or more HMX):

Procedure:

500 grams of HMX containing 12.25% RDX are placed in a 1500 cc beaker, 500 cc of acetone is added and the slurry is agitated for several minutes at room temperature. Before complete settling, the RDX-HMX-acetone solution is decanted.

To the residual HMX-RDX, another 500 cc of acetone is added. The slurry is heated on the steambath and while boiling, agitated for several minutes. The boiling RDX-HMX-acetone solution is decanted. The residual HMX is now washed with cold acetone into a funnel. This HMX is now taken up in 95% alcohol, filtered and dried. Yield 353.9 gm or 70.78%.

All the acetone extracts are combined and evaporated to dryness. Yield 137.5 gm or 26.5%.

Yield Balance:

| | |
|---|---|
| Pure HMX obtained - 353.9 gm | 70.78% |
| Total RDX-HMX mixture recovered - 137.5 gm | 26.50% |
| Samples taken during process - 2.4 gm | 0.48% |
| Loss during process | 2.24% |
| Total | 100.00% |

Various samples were analyzed for RXD content:

| | |
|---|---|
| 1. Crude HMX | 12.25% RDX |
| 2. After first acetone washing | 6.0% RDX |
| 3. After second acetone washing | 2.0% RDX |
| 4. After third acetone washing | 0.0% RDX |
| RDX-HMX sample recovered | 54.5% RDX |

Preparation of Fine Particle-size HMX by the Aspirator Method:

1. Dissolve 1100 gm HMX in 4400 cc of dimethyl sulfoxide.
2. Filter the HMX solution.
3. Connect a clean aspirator to the water line.
4. Place a 55 gallon clean drum under the aspirator.
5. Fasten a polyethylene tubing, long enough to reach easily to the bottom of the HMX-dimethyl sulfoxide container, to the side intake of the aspirator.
6. Fasten to the bottom of the aspirator another polyethylene tube long enough to reach to the bottom of the 55 gallon drum.
7. Open the water faucet and then place the polyethylene tube in the HMX container.
8. White milky fine HMX separates out in the drum. Total duration of run is approximately 7 minutes.
9. After all the HMX solution is sucked out of the container, the water is turned off.
10. The material is filtered and water washed.
11. If dry HMX is required, the material can be alcohol and ether washed.

A more efficient method to recover the RDX-HMX mixture:

1. Filter the combined hot acetone extracts.
2. Pour while agitating the filtered extracts into at least 4 times its volume of water.
3. Filter and dry, etc.

beta-HMX

Color:

White

Storage:

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group L (dry)<br>Group M (wet) |
| Exudation | None |

References:[37]

(a) O. E. Sheffield, E. J. Murray, A. L. Rosen and B. W. Kanouse, Properties of HMX, PA Chemical Research Laboratory Report No. 52-TM1-23, 7 April 1952.

(b) W. E. Bachmann, The Preparation of HMX, OSRD Report No. 1981, 3 November 1943.

(c) S. Livingston, Characteristics of Explosives HMX and DPEHN, PATR No. 1561, 6 September 1945.

(d) R. J. Finkelstein and G. Gamow, Theory of the Detonation Process, NAVORD Report No. 90-46, 20 April 1947.

(e) O. H. Johnson, HMX as a Military Explosive, NAVORD Report No. 4371, 1 October 1956.

(f) Also see the following Picatinny Arsenal Technical Reports on HMX:

| 1 | 3 | 6 | 7 | 9 |
|---|---|---|---|---|
| 1741 | 2183 | 2016 | 1737 | 1709<br>2059 |

(g) C. Lenchitz, W. Beach and R. Valicky, Enthalpy Changes, Heat of Fusion and Specific Heat of Basic Explosives, PATR No. 2504, January 1959.

[37] See footnote 1, page 10.

HTA-3

**Composition:**

| | % |
|---|---|
| HMX | 49 |
| TNT | 29 |
| Aluminum | 22 |
| C/H Ratio | |

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | -- |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 17 |
| Sample Wt, mg | 25 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | Unaffected |

**Rifle Bullet Impact Test:** 10 Trials, %

| | 3/16" Steel | 1/8" Al |
|---|---|---|
| Explosions | 90 | 50 |
| Partials | -- | -- |
| Burned | 10 | -- |
| Unaffected | 0 | 50 |

**Explosion Temperature:**

| Seconds, 0.1 (no cap used) | °C |
|---|---|
| 1 | --- |
| 5 Flames erratically | 370 |
| 10 | |
| 15 | |
| 20 | |

**75°C International Heat Test:**
% Loss in 48 Hrs

**100°C Heat Test:**
% Loss, 1st 48 Hrs
% Loss, 2nd 48 Hrs
Explosion in 100 Hrs

**Flammability Index:**

**Hygroscopicity:** %

**Volatility:**

**Molecular Weight:** 91

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -51 |
| CO % | -27 |

**Density:** gm/cc Cast 1.90

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Vacuum Stability Test:**

| cc/40 Hrs, at | |
|---|---|
| 90°C | ---- |
| 100°C | ---- |
| 120°C | 0.37 |
| 135°C | |
| 150°C | |

**200 Gram Bomb Sand Test:**
Sand, gm 61.3

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | ---- |
| Lead Azide | 0.30 |
| Tetryl | ---- |

**Ballistic Mortar, % TNT:** 120

**Trauzl Test, % TNT:**

**Plate Dent Test:**
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**Detonation Rate:**

| | |
|---|---|
| Confinement | None |
| Condition | Cast |
| Charge Diameter, in. | 1.0 |
| Density, gm/cc | 1.90 |
| Rate, meters/second | 7866 |

**Booster Sensitivity Test:**
- Condition
- Tetryl, gm
- Wax, in. for 50% Detonation
- Wax, gm
- Density, gm/cc

**Heat of:**

| | |
|---|---|
| Combustion, cal/gm | 3687 |
| Explosion, cal/gm | 1190 |
| Gas Volume, cc/gm | 680 |
| Formation, cal/gm | ---- |
| Fusion, cal/gm | |

**Specific Heat:** cal/gm/°C

| | |
|---|---|
| 32° to 74°C | 0.245 |

**Burning Rate:**
- cm/sec

**Thermal Conductivity:**
- cal/sec/cm/°C

**Coefficient of Expansion:**
- Linear, %/°C
- Volume, %/°C

**Hardness, Mohs' Scale:**

**Young's Modulus:**
- E', dynes/cm²
- E, lb/inch²
- Density, gm/cc

**Compressive Strength:** lb/inch²

| | |
|---|---|
| | 2260 |
| | See below |

**Vapor Pressure:**

| °C | mm Mercury |
|---|---|

**Compressive Strength:** lb/inch²

| | |
|---|---|
| | * |
| Average (10 tests) | 2260 |
| High | 2530 |
| Low | 1910 |

**Decomposition Equation:**
- Oxygen, atoms/sec (Z/sec)
- Heat, kilocalorie/mole (ΔH, kcal/mol)
- Temperature Range, °C
- Phase

**Armor Plate Impact Test:**

**60 mm Mortar Projectile:**
- 50% Inert, Velocity, ft/sec
- Aluminum Fineness

**500-lb General Purpose Bombs:**

Plate Thickness, inches
- 1
- 1¼
- 1½
- 1¾

**Bomb Drop Test:**

**T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:**

Max Safe Drop, ft

**500-lb General Purpose Bomb vs Concrete:**
- Height, ft
- Trials
- Unaffected
- Low Order
- High Order

**1000-lb General Purpose Bomb vs Concrete:**
- Height, ft
- Trials
- Unaffected
- Low Order
- High Order

**Ultimate Deformation:** %

| | |
|---|---|
| Average (10 tests) | 2.81 |
| High | 3.22 |
| Low | 2.52 |

* Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**Fragment Velocity:** ft/sec

At 9 ft

At 25½ ft

Density, gm/cc

**Blast (Relative to TNT):**

**Air:**

Peak Pressure

Impulse

Energy

**Air, Confined:**

Impulse

**Under Water:**

Peak Pressure

Impulse

Energy

**Underground:**

Peak Pressure

Impulse

Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Gray

**Principal Uses:** HE projectile and bomb filler

**Method of Loading:** Cast

**Loading Density:** gm/cc 1.90

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | None |

Work to Produce Rupture: ft-lb/inch$^3$ *

| | |
|---|---|
| Average (10 tests) | 2.77 |
| High | 3.39 |
| Low | 2.40 |

Efflux Viscosity, Saybolt Seconds: 24.8

*Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.

Modulus of Elasticity: *

| | lb/inch$^2$ |
|---|---|
| Average | 89,200 |
| High | 97,400 |
| Low | 76,300 |

* Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.

Setback Sensitivity Test: (a)

| | |
|---|---|
| Critical Pressure | 119,000 psi * |
| Density, gm/cc | 1.92 |

* Pressure below which no initiation is obtained and above which an increasing percentage of initiations can be expected as the setback pressure increases.

Preparation:

Procedure similar to that used for Torpex.

References:[38]

(a) 1st Indorsement from Chief, Explosives Development Section, to Chief, Explosives Research Section, Picatinny Arsenal, dated 12 May 1958. Subject: "Properties of Octols and HTA-3."

(b) R. Brown and R. Velicky, Heat Capacity of HTA-3, Picatinny Arsenal General Laboratory Report No. 58-H1-509, 5 May 1958.

[38]See footnote 1, page 10.

**Composition:**

| | % |
|---|---|
| N | 28.8 |
| Pb | 71.2 |

$N{\equiv}N{=}N{-}Pb{-}N{=}N{\equiv}N$

C/H Ratio

**Impact Sensitivity, 2 Kg Wt:**

| | Pure | Dextrinated |
|---|---|---|
| Bureau of Mines Apparatus, cm | 10 | 17 |
| Sample Wt 20 mg | | |
| Picatinny Arsenal Apparatus, in. | 3 | 5 |
| Sample Wt, mg | 30 | 28 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Explodes |
| Fiber Shoe | Explodes |

**Rifle Bullet Impact Test:**

| | Trials % |
|---|---|
| Explosions | |
| Partials | |
| Burned | |
| Unaffected | |

**Explosion Temperature:**

| Seconds, 0.1 (no cap used) | °C 396 |
|---|---|
| 1 | 356 |
| 5 Explodes | 340 |
| 10 | 335 |
| 15 | 335 |
| 20 | 335 |

**75°C International Heat Test:**
% Loss in 48 Hrs

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.34 |
| % Loss, 2nd 48 Hrs | 0.05 |
| Explosion in 100 Hrs | None |

**Flammability Index:**

**Hygroscopicity:** %

| | Dextrinated | Not Dextrinated |
|---|---|---|
| 30°C, 90% RH | 0.8 | 0.03 |

**Volatility:**

**Molecular Weight:** ($PbN_6$) 291

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -5.5 |
| CO % | -5.5 |

**Density:** gm/cc

| | |
|---|---|
| Crystal | 4.80 |
| Dextrinated | 4.38 |

**Melting Point:** °C Decomposes

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Vacuum Stability Test:**

| | Dextrinated |
|---|---|
| cc/40 Hrs, at 90°C | |
| 100°C | 1.0 |
| 120°C | 0.07 |
| 135°C | |
| 150°C | |

**200 Gram Bomb Sand Test:**

| Sand, gm | |
|---|---|
| Black powder fuse | 19.0 |

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm
Mercury Fulminate
Lead Azide
Tetryl

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:** (a) 39

**Plate Dent Test:**
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**Detonation Rate:**

| | Pure Lead Azide | | |
|---|---|---|---|
| Confinement | | | |
| Condition | Pressed | | |
| Charge Diameter, in. | | | |
| Density, gm/cc | 2.0 | 3.0 | 4.0 |
| Rate, meters/second | 4070 | 4630 | 5180 |

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**Fragment Velocity:** ft/sec

At 9 ft

At 25½ ft

Density, gm/cc

**Blast (Relative to TNT):**

**Air:**

Peak Pressure

Impulse

Energy

**Air, Confined:**

Impulse

**Under Water:**

Peak Pressure

Impulse

Energy

**Underground:**

Peak Pressure

Impulse

Energy

Heat of:

| | |
|---|---|
| Combustion, cal/gm | 630 |
| Explosion, cal/gm | 367 |
| Gas Volume, cc/gm | 308 |
| Formation, cal/gm | -346 |

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** White-buff

**Principal Uses:** Detonators, priming compositions, and commercial blasting caps

**Method of Loading:** Pressed

**Loading Density:** gm/cc

| psi x $10^3$ | | | |
|---|---|---|---|
| 3 | 5 | 10 | 15 |
| 2.62 | 2.71 | 2.96 | 3.07 |

**Storage:**

| | |
|---|---|
| Method | Wet |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group M (wet) |
| Exudation | None |

Compatibility with Metals:

Dry lead azide does not react with or corrode steel, iron, nickel, aluminum, lead, zinc, copper, tin or cadmium. It does not affect coatings of acid-proof black paint, oil, NRC compound or shellac. Lead azide in the presence of moisture corrodes zinc and copper; and with copper, it forms the extremely sensitive and dangerous copper azide.

Specific Heat: cal/gm/°C

| °C | |
|---|---|
| -50 | 0.110 |
| 0 | 0.110 |
| 25 | 0.110 |
| 50 | 0.110 |

Thermal Conductivity:

cal/sec/cm/°C (Pure) $1.55 \times 10^{-4}$

Compatibility with Metals:

Dry: Steel, iron, nickel, aluminum, lead, zinc, copper, tin, stainless steel, brass and bronze were unaffected by six years' contact with dry lead azide at ambient temperature and 50°C. Monel, chrome-nickel and Inconel were unaffected under the same conditions in two and one-half years.

Wet: Copper and zinc are rapidly attacked by moist lead azide, while aluminum is not attacked in 24 hours. Monel, chrome-nickel and Inconel are not attacked by lead azide ($\frac{1}{2}$% moisture) after 29 months' exposure at ambient temperature and 50°C, and J-1 magnesium-aluminum alloy is very slightly corroded.

| Sample Tested | Lead Azide Dry | Lead Azide plus 25% Water | Lead Azide plus 20% Water | Lead Azide plus 20% Ethyl Alcohol (95%) |
|---|---|---|---|---|
| Friction Pendulum Test: | | | | |
| (All LA dextrinated) | | | | |
| Shoe | Fiber | Fiber | Steel | Fiber | Steel | Fiber |
| No. of Trials | 1 | 10 | 12 | 10 | 4 | 1 |
| Explosions | 1 | 0 | 0 | 0 | 1 | 1 |
| Cracklings | | 0 | 2 | 0 | 2 | 0 |
| Unaffected | 0 | 10 | 10 | 10 | 1 | 0 |
| Impact Sensitivity, 2 Kg Wt: | | | | | | |
| (All LA dextrinated) | | | | | | |
| PA Apparatus, inches | 4 | 9 | | 9 | | 4 |

Activation Energy: (c)

| | |
|---|---|
| Kcal/mole | 23.74 |
| Induction Period, seconds | 0.5-10 |

Initiating Efficiency, Grams Required to Give Complete Initiations of:

| | Dextrinated Azide (gm) |
|---|---|
| TNT | 0.25 |
| Tetryl | 0.10 |
| RDX | 0.05 |
| PETN | 0.02 |

Sensitivity to Static Discharge, Joules (Pure Lead Azide) (b) 0.0070

Compatibility of Dextrinated Lead Azide with Black Powder:
100°C Vacuum Stability Test, cc/40 hr:

| Sample Wt (gm) | Material | cc |
|---|---|---|
| 1.0 | Lead Azide | 0.50 |
| 1.0 | Black Powder | 0.38 |
| 2.0 | 50/50, Lead Azide/Black Powder | 1.26 |

Solubility of Pure Lead Azide; gm/100 gm of Water:

| °C | % |
|---|---|
| 20 | 0.05 |

Preparation of Lead Azide (Dextrinated): (du Pont procedure)

$$2\,Na - N = N \equiv N + Pb(NO_3)_2 \rightarrow Pb(N_3)_2 + 2\,NaNO_3$$

Lead nitrate solution: This is prepared by dissolving 164 lbs lead nitrate and 8.25 lbs dextrine in deionized water, the solution allowed to settle, and sodium hydroxide added to bring the solution to a pH of 5.4. The final concentration of the solution is then adjusted to 7.4% lead nitrate, 0.375% dextrine by addition of deionized water.

The lead azide is precipitated at a solution temperature of 160°F, using 60 parts lead nitrate and 50 parts sodium azide solution. The latter is added to the former in 23 minutes, under agitation (no baffles are used in the precipitation vessel), the mixture cooled to room temperature in 12 minutes, and allowed to settle 10 minutes. The mother liquor is decanted and the remaining slurry washed before packing.

Origin:

First prepared in 1891 by T. Curtius (Ber 24, 3345-6) by adding lead acetate to a solution of sodium or ammonium azide. F. Hyronimus (French Patent 384,792) should be credited with the first attempt in 1907 to use lead azide with some success in the explosive industry. Its commercial manufacture started in Europe before World War II and in the United States since 1931 as military or commercial grade "dextrinated" lead azide.

Destruction by Chemical Decomposition:

Lead azide can be decomposed by

(1) mixing with at least five times its weight of a 10% solution of sodium hydroxide and allowing the mixture to stand for 16 hours. Decant the supernatant solution of sodium azide and drain into the soil.

(2) dissolving in a 10% solution of ammonium acetate and adding a 10% solution of sodium or potassium bichromate until no more lead chromate is precipitated.

(3) wetting with 500 times its weight of water, slowly adding 12 times its weight of 25% sodium nitrite, stirring, and then adding 14 times its weight of 36% nitric or glacial acetic acid. A red color produced by the addition of ferric chloride solution indicates Lead Azide is still present.

(4) dissolving in 50 times its weight of 15% ceric ammonium nitrate. The azide is decomposed with the evolution of nitrogen.

References: [39]

(a) Ph. Naoum, Z ges Schiess Sprengstoffw, 181, 229, 267 (27 June 1932).

(b) F. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.

(c) C. Lenchitz, Ice Calorimeter Determination of Enthalpy and Specific Heat of Eleven Organometallic Compounds, PATR #2224, November 1955.

(d) Also see the following Picatinny Arsenal Technical Reports on Lead Azide:

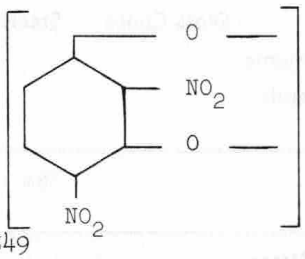
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 550 | 561 | 832 | 393 | 534 | 255 | 326 | 567 | 628 | 609 |
| 580 | 861 | 852 | 1393 | 784 | 525 | 856 | 637 | 708 | 719 |
| 600 | 1451 | 882 | 1493 | 824 | 1325 | 866 | 657 | 748 | 749 |
| 760 | 1651 | 932 | 2093 | 944 | 1485 | 1316 | 707 | 788 | 769 |
| 1450 | | 1132 | 2133 | 2164 | | 1486 | 1737 | 838 | 849 |
| | | 1152 | | 2204 | | 1556 | 2227 | 1388 | 999 |
| | | 1352 | | | | | | 1528 | 2179 |
| | | 1372 | | | | | | 1838 | |
| | | | | | | | | 2198 | |

[39] See footnote 1, page 10.

# Lead 2,4-Dinitroresorcinate (LDNR)

**Composition:**

| | % |
|---|---|
| C | 17.8 |
| H | 0.5 |
| N | 6.9 |
| O | 23.7 |
| Pb | 51.1 |




C/H Ratio 0.549

**Molecular Weight:** $(PbC_6H_2N_2O_6)$ 405

**Oxygen Balance:**
$CO_2$ % -32
CO % - 8

**Density:** gm/cc Crystal 3.2

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^D$ $n_{25}^D$ $n_{30}^D$

**Impact Sensitivity, 2 Kg Wt:**
Bureau of Mines Apparatus, cm 1 kg wt 30
Sample Wt 20 mg
Picatinny Arsenal Apparatus, in.
Sample Wt, mg 20

**Vacuum Stability Test:**
cc/40 Hrs, at
90°C
100°C
120°C (73 minutes) Explodes
135°C
150°C

**Friction Pendulum Test:**
Steel Shoe
Fiber Shoe

**200 Gram Bomb Sand Test:**
Sand, gm
Black powder fuse 20

**Rifle Bullet Impact Test:** Trials

| | % |
|---|---|
| Explosions | |
| Partials | |
| Burned | |
| Unaffected | |

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm
Mercury Fulminate
Lead Azide
Tetryl

**Explosion Temperature:** °C
Seconds, 0.1 (no cap used)

| | | |
|---|---|---|
| 1 | | |
| 5 | Explodes | 265 |
| 10 | | |
| 15 | | |
| 20 | | |

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**75°C International Heat Test:**
% Loss in 48 Hrs

**Plate Dent Test:**
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.20 |
| % Loss, 2nd 48 Hrs | 0.02 |
| Explosion in 100 Hrs | None |

**Detonation Rate:**
Confinement
Condition
Charge Diameter, in.
Density, gm/cc
Rate, meters/second

**Flammability Index:**

**Hygroscopicity:** % 30°C, 90% RH 0.73

**Volatility:**

# Lead 2,4-Dinitroresorcinate (LDNR)

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Red or yellow

**Principal Uses:** Electric detonators

**Method of Loading:** Pressed

**Loading Density:** gm/cc

**Storage:**

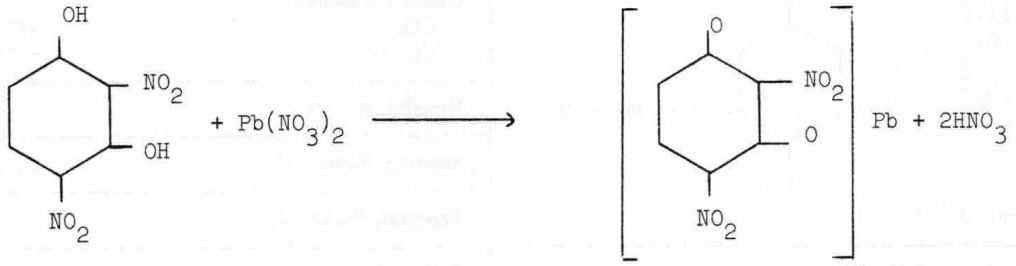
| | |
|---|---|
| Method | Wet |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | |
| Exudation | None |

Initiating Efficiency: 0.4 gm LDNR does not initiate tetryl pressed at 3000 psi.

Heat of:

| | |
|---|---|
| Explosion, cal/gm | 270 |

Preparation:




To a solution of 5 grams of purified dinitroresorcin and 2.65 grams of anhydrous sodium carbonate in 500 cc of boiling water is added slowly a solution of 10 grams of lead nitrate dissolved in 60 cc of boiling water. The reaction mixture is constantly stirred during the addition of the lead salt and for about an hour afterward while the solution is allowed to cool to room temperature. The precipitate is filtered and washed thoroughly first with water and then with alcohol and ether. It is dried in a steam oven.

Origin:

2,4-dinitroresorcin was described in the 1881 edition of Beilstein (Beil VII, 885). The same compound was described in more detail by Weselsky, Benedikt and Hübl in 1882 (M II, 323). The lead salt of 2,4-dinitroresorcinol appears to have been prepared between World War I and World War II by treating resorcinol with nitrous acid and oxidizing the resulting dinitroso-resorcinol to dinitroresorcinol. Lead nitrate solution was then added to a solution of the 2,4-dinitroresorcinol to which sodium carbonate had been added to form the soluble sodium salt (J. D. Hopper, PATR No. 480, March 1934). The LDNR exists in two forms differing in physical characteristics but possessing similar explosive properties. These forms are red and orange in color (K. S. Warren, PATR 1448, September 1944).

References:[40]

(a) See the following Picatinny Arsenal Technical Reports on Lead 2,4-Dinitroresorcinate:

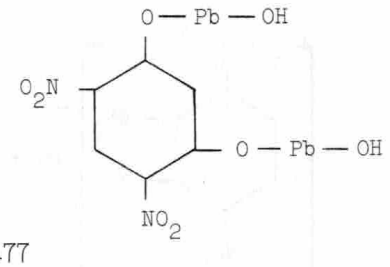
| 0 | 3 | 4 | 8 | 9 |
|---|---|---|---|---|
| 480 | 453 | 1004 | 1328 | 859 |
| 580 | | | 1448 | 1079 |

[40]See footnote 1, page 10.

# Lead 4,6-Dinitroresorcinol Basic (LDNR Basic)

**Composition:**

| | % |
|---|---|
| C | 11.2 |
| H | 0.6 |
| N | 4.3 |
| O | 19.8 |
| Pb | 64.1 |




C/H Ratio 0.177

**Molecular Weight:** $(Pb_2C_6H_4N_2O_8)$ 646

**Oxygen Balance:**
$CO_2$ % -20
CO % - 5

**Density:** gm/cc

**Melting Point:** °C 213

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^D$ $n_{25}^D$ $n_{30}^D$

**Impact Sensitivity, 2 Kg Wt:**
Bureau of Mines Apparatus, cm 1 kg wt 60
Sample Wt 20 mg
Picatinny Arsenal Apparatus, in.
Sample Wt, mg 20

**Friction Pendulum Test:**
Steel Shoe
Fiber Shoe

**Vacuum Stability Test:**
cc/40 Hrs, at
90°C
100°C
120°C
135°C
150°C

**Rifle Bullet Impact Test:** Trials / %
Explosions
Partials
Burned
Unaffected

**200 Gram Bomb Sand Test:**
Sand, gm
Black powder fuse 15

**Explosion Temperature:** °C
Seconds, 0.1 (no cap used)
1
5 Explodes 295
10
15
20

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm
Mercury Fulminate
Lead Azide
Tetryl

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**75°C International Heat Test:**
% Loss in 48 Hrs

**Plate Dent Test:**
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**100°C Heat Test:**
% Loss, 1st 48 Hrs 0.4
% Loss, 2nd 48 Hrs 0.0
Explosion in 100 Hrs None

**Detonation Rate:**
Confinement
Condition
Charge Diameter, in.
Density, gm/cc
Rate, meters/second

**Flammability Index:**

**Hygroscopicity:** %

**Volatility:**

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Red or yellow

**Principal Uses:** Electric detonators

**Method of Loading:** Pressed

**Loading Density:** gm/cc

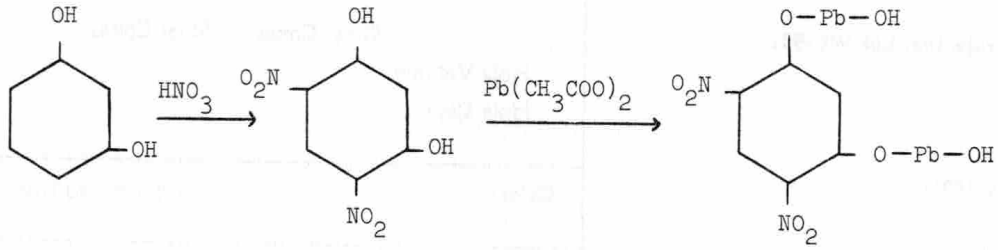
**Storage:**

| | |
|---|---|
| Method | Wet |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | |
| Exudation | None |

Initiating Efficiency: 0.4 gm LDNR Basic does not initiate tetryl pressed at 3000 psi.

## Lead 4,6-Dinitroresorcinol Basic (LDNR Basic)

Preparation:




(a) One hundred grams of pure resorcin is fused in a porcelain casserole and immediately poured on a glass plate. After cooling, the cake is ground in a mortar to pass a U. S. Standard No. 6 mesh screen. Four hundred grams of 98 percent nitric acid in a one pint capacity Dewar jar is stirred mechanically while carbon dioxide snow is added in small pieces. When the temperature falls to -20°C, 40 grams of the granulated resorcin is added in small quantities. Simultaneous addition of solid carbon dioxide as required prevents a rise of temperature of more than 5 degrees throughout the entire experiment. Five minutes after the last portion of resorcin is introduced, the mixture is further cooled to minus 50°C, and finally drowned with vigorous stirring in five times its volume of cracked ice, in water. This mixture is allowed to stand for one hour and the product then filtered, washed, and partially dried, weight 43.6 grams. The crude 4,6-DNR is purified by first dissolving the product in an aqueous 5 percent sodium hydroxide solution (17.4 grams of sodium hydroxide in 340 cc of water). The resulting solution is then neutralized by gradually adding it to a boiling solution of 21.4 grams of 98 percent sulphuric acid in 150 cc of water. The resulting precipitate of 4,6-DNR is filtered hot on a suction filter and air-dried. Yield, 27.5 grams (37.8 percent of the theoretical).

(b) Five hundredths (0.05) mole (18.96 grams) of lead acetate is dissolved in 67 cc of warm water, into which is gradually stirred 0.10 mole (4.0 grams) of sodium hydroxide dissolved in 67 cc of water. Stirring is continued for five minutes. After settling, the white lead hydroxide is washed by decantation three times with 100 cc portions of distilled water, and used immediately for the next operation.

(c) A 0.0278 mole (5.56 grams) quantity of the 4,6-DNR prepared under (a) above, is dispersed in 270 cc of water by vigorously beating with a motor stirrer. After heating this dispersion to 90°C, the 0.05 mole of lead hydroxide prepared above in slurry form is introduced in small portions. Agitation is continued for three hours at 90°C. The basic lead 4,6-DNR is washed once by decantation, and again on the filter with alcohol. After drying overnight in a desiccator charged with calcium chloride, the product weighs 15.6 grams.

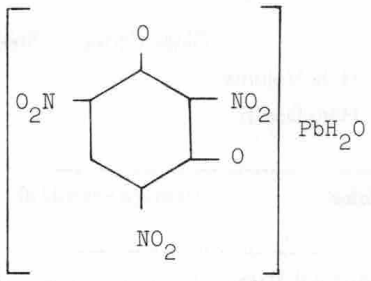
Origin:

Both the 2,4- and 4,6-dinitroresorcin were described in some detail by Weselsky, Benedikt and Hübl in 1882 (M II, 323). Typke prepared the 4,6-dinitroresorcin in 1883 by hydrolyzing the nitration product of resorcin diacetate (Ber 16, 551). A more direct and economical method of preparation suitable for production scale manufacture was developed during World War II by the British (Ministry of Supply Pouch Item W-154-21a, "Manufacture of 4,6-Dinitroresorcin and Lead 4,6-Dinitroresorcinate"). This procedure consisted of preparing 4,6-dinitroresorcinol by direct nitration of granulated resorcin and allowing the product in slurry to react with an excess of lead hydroxide at 90°C. This basic salt can be prepared in two forms: (1) a micro-crystalline, yellow, low-density form and (2) a denser, brick-red form. Both products have the same chemical composition and the same sensitivity to impact (PATR 1448, September 1944).

# Lead Styphnate

**Composition:**

| | % |
|---|---|
| C | 15.4 |
| H | 0.6 |
| N | 9.0 |
| O | 30.8 |
| Pb | 44.2 |




C/H Ratio 0.320

**Molecular Weight:** ($PbC_6H_3N_3O_9$) 468

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -19 |
| CO % | 2 |

**Density:** gm/cc Crystal 3.02

**Melting Point:** °C Explodes 260-310

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 17 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. 3; (8 oz wt) | 8 |
| Sample Wt, mg | 22 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Detonates |
| Fiber Shoe | Detonates |

**Vacuum Stability Test:**

cc/40 Hrs, at

| | |
|---|---|
| 90°C | |
| 100°C | 0.4 |
| 120°C | 0.3 |
| 135°C | |
| 150°C | |

**Rifle Bullet Impact Test:**

| | Trials | % |
|---|---|---|
| Explosions | | |
| Partials | | |
| Burned | | |
| Unaffected | | |

**200 Gram Bomb Sand Test:**

| | |
|---|---|
| Sand, gm | 24 |
| Black powder fuse | 11.1 |

**Explosion Temperature:** °C

Seconds, 0.1 (no cap used)

| | | |
|---|---|---|
| 1 | | |
| 5 | Explodes | 282 |
| 10 | | 276 |
| 15 | | 272 |
| 20 | | 267 |

**Sensitivity to Initiation:**

Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | Trace* |
| Lead Azide | Trace* |
| Tetryl | |

* <.001 gm, alternative

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:** (a) 40

**75°C International Heat Test:**

% Loss in 48 Hrs

**Plate Dent Test:**

Method

Condition

Confined

Density, gm/cc

Brisance, % TNT

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.38 |
| % Loss, 2nd 48 Hrs | 0.73 |
| Explosion in 100 Hrs | None |

**Detonation Rate:**

| | |
|---|---|
| Confinement | |
| Condition | |
| Charge Diameter, in. | |
| Density, gm/cc | 2.9 |
| Rate, meters/second | 5200 |

**Flammability Index:**

**Hygroscopicity:** % 25°C, 100% RH 0.05

30°C, 90% RH 0.02

**Volatility:**

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**Fragment Velocity:** ft/sec

At 9 ft

At 25½ ft

Density, gm/cc

**Blast (Relative to TNT):**

**Air:**

Peak Pressure

Impulse

Energy

**Air, Confined:**

Impulse

**Under Water:**

Peak Pressure

Impulse

Energy

**Underground:**

Peak Pressure

Impulse

Energy

Heat of:

| | |
|---|---|
| Combustion, cal/gm | 1251 |
| Explosion, cal/gm | 457 |
| Gas Volume, cc/gm | 368 |
| Formation, cal/gm | -92 |

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Orange-reddish brown

**Principal Uses:** Igniting charge, and ingredient of priming compositions

**Method of Loading:** Pressed

**Loading Density:** gm/cc

**Storage:**

| | |
|---|---|
| Method | Wet |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group M (wet) |
| Exudation | None |

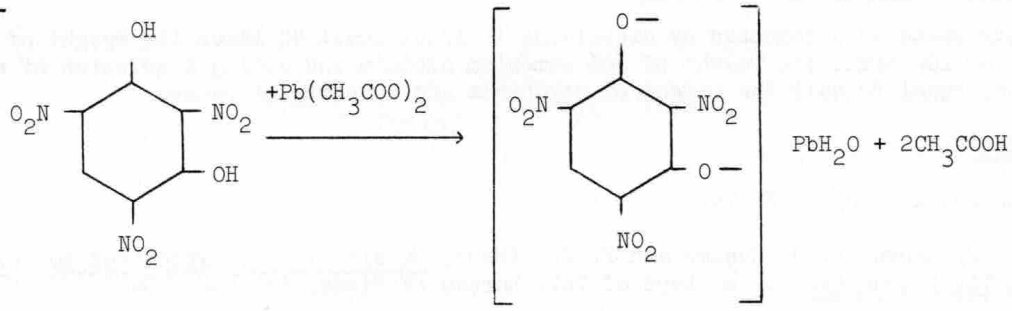
Activation Energy:

| | |
|---|---|
| kcal/mol | 75.39 |
| Induction Period, sec | 0.5-10 |

Specific Heat: cal/cm/°C (c)

| °C | |
|---|---|
| -50 | 0.141 |
| 0 | 0.158 |
| 25 | 0.164 |
| 50 | 0.167 |

Preparation:




Dissolve 14.4 gm lead nitrate and 1 cc of 36% acetic acid in 320 cc distilled water. Dissolve 4 gm 2,4,6-trinitroresorcinol and 1.73 gm sodium carbonate in 80 cc distilled water. Add the lead acetate solution to the trinitroresorcinol solution, under agitation, keeping the temperature at 70°-75°C and continue stirring for 3 hours at this temperature. Cool to 20°C in 5 hours. Evaporate the solution to 1/3 its volume, cool, filter and wash the product well with water (to neutrality).

Sensitivity to Static Discharge, joules: (b) 0.0009

Loss in Weight at 105°C: %

| | |
|---|---|
| 3 hours | 0.02 |
| 6 hours | 0.23 |
| 9 hours | 0.23 |

Effect of Storage for 2 Months at 80°C, on:

| | |
|---|---|
| Explosion Temperature Test Value | Nil |
| Sand Test Value | Nil |
| Sensitivity to Initiation | Nil |

Solubility, gm/100 gm (%) in:

| Glycol Diacetate | |
|---|---|
| °C | % |
| 20-25 | 0.1 |

Origin:

First described in 1914 by von Hurtz and found to be a relatively poor initiator by Wallbaum in comparison to other primary explosives. (Z ges Schiess Sprengstoffw 34, 126, 161, 197 (1939)). Moisak showed that lead styphnate could be used as an insulating (cover) material for lead azide providing protection from mechanical and chemical influences and, at the same time, increasing the detonating ability of the total charge (Transactions of Butlerov Inst Chem Tech Kasan (Russia) 2, 81-5 (1935).

Destruction by Chemical Decomposition:

Lead styphnate is decomposed by dissolving it in at least 40 times its weight of 20% sodium hydroxide or 100 times its weight of 20% ammonium acetate and adding a solution of sodium dichromate, equal to half the weight of styphnate and 10 parts of water.

References:[41]

(a) Report AC-956/Org Ex 74.

(b) F. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.

(c) C. Lenchitz, Ice Calorimeter Determination of Enthalpy and Specific Heat of Eleven Organometallic Compounds, PATR No. 2224, November 1955.

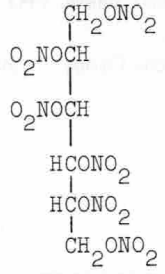
(d) Also see the following Picatinny Arsenal Technical Reports on Lead Styphnate:

| 0 | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| 1450 | 11 | 1352 | 453 | 2164 | 1316 | 407 | 318 | 2179 |
| 2220 | | 2032 | 2093 | | | 1737 | | |
| | | | | | | 2077 | | |

[41]See footnote 1, page 10,

**Composition:**

| | % |
|---|---|
| C | 15.9 |
| H | 1.8 |
| N | 18.6 |
| O | 63.8 |
| C/H Ratio | 0.133 |



**Molecular Weight:** $(C_6H_8N_6O_{18})$ 452

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | 7.1 |
| CO % | 28.3 |

**Density:** gm/cc 1.73

**Melting Point:** °C 112-113

**Freezing Point:** °C

**Boiling Point:** °C Decomposes 150

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 11 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 4 |
| Sample Wt, mg | 11 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Detonates |
| Fiber Shoe | Unaffected |

**Vacuum Stability Test:**

cc/40 Hrs, at
90°C
100°C
120°C
135°C
150°C

**Rifle Bullet Impact Test:**

| | Trials | % |
|---|---|---|
| Explosions | | |
| Partials | | |
| Burned | | |
| Unaffected | | |

**200 Gram Bomb Sand Test:**

Sand, gm 68.5

**Explosion Temperature:** °C

| Seconds, 0.1 (no cap used) | 160-170 | (a) |
|---|---|---|
| 1 | 232 | (b) |
| 5 | 175 | (c) |
| 10 | | |
| 15 | | |
| 20 | | |

**Sensitivity to Initiation:**

Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | -- |
| Lead Azide | 0.06 |
| Tetryl | -- |

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:** (c) 172

**75°C International Heat Test:**

% Loss in 48 Hrs 0.4

**Plate Dent Test:**

Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | -- |
| % Loss, 2nd 48 Hrs | -- |
| Explosion in 100 Hrs (Frothed) | 48 hours |

**Detonation Rate:** (d)

| | |
|---|---|
| Confinement | Yes |
| Condition | Pressed |
| Charge Diameter, in. | 0.5 |
| Density, gm/cc | 1.73 |
| Rate, meters/second | 8260 |

**Flammability Index:**

**Hygroscopicity:** % 30°C, 90% RH 0.17

**Volatility:**

# Mannitol Hexanitrate (Nitromannite)

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:**

**Principal Uses:** Secondary charge in detonators (ref i), and in blasting caps designed to be initiated by a fuse (ref j)

**Method of Loading:** Pressed

**Loading Density:** gm/cc

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | |
| Exudation | None |

65.5°C KI Test:

| | |
|---|---|
| Minutes | 6 |

Heat of: (e, f, g)

| | | | | |
|---|---|---|---|---|
| Combustion, cal/gm | 1515 | | 1525 | |
| Explosion, cal/gm | 1390 | 1454 | 1468 | 1520 |
| Formation, cal/gm | 337 | 345 | 366 | |

## Mannitol Hexanitrate (Nitromannite)

Solubility:

a. Insoluble in water.

b. Slightly soluble in cold alcohol (2.9 gm at 13°C).

c. Slightly soluble in ether (4 gm at 9°C).

d. Very soluble in hot alcohol.

Preparation: (Laboratory Method) (k)

a. Cool to below 0°C, 50 gm of 98%-100% nitric acid placed in a 300 milliliter Erlenmeyer Pyrex flask provided with a thermometer and immersed in an ice-salt mixture.

b. Introduce in small portions, 10 gm of d-mannitol, while swirling the flask to break up any lumps of mannite which might form. Keep the temperature below 0°C.

c. After solution is complete, add 100 gm of concentrated sulfuric acid from a dropping funnel, swirling the flask in an ice-salt mixture to keep the temperature below 0°C.

d. Filter the resulting porridge-like slurry through a filter paper previously hardened by treatment with mixed acid.

e. Rinse the precipitate directly on the filter with water followed by dilute aqueous sodium carbonate and finally with water. (The resulting crude mannitol hexanitrate gives 18.2% N as determined by the nitrometer.)

f. Dissolve the crude mannitol hexanitrate in boiling alcohol and filter through a water-heated funnel.

g. Bring the filtrate to boiling and gradually add hot water until the appearance of the first turbidity.

h. Cool in an ice-salt bath, separate and dry the crystals. (Yield should be about 23 gm of material, melting at 112°-113°C and having 18.58% N, the nitrogen being determined by the nitrometer. Theoretical yield would be 24.8 gm.)

Origin:

Mannitol hexanitrate was discovered in 1847 by Ascanio Sobrero who recommended it as a substitute for mercury fulminate in percussion caps (Comp rend, 1847, 121). It is the hexanitric ester of d-mannitol which is widely distributed in nature, particularly in the plant Fraxinus ornus. N. Sokoloff, a Russian chemist, investigated the explosive properties of HM and recommended in 1878 a method of preparation. Mannitol hexanitrate was thoroughly studied by Berthelot, Sarran and Vieille, Domonte, Menard, Strecker, Tichanowich (Ph. Naoum, Nitroglycerin and Nitroglycerin Explosives, Baltimore, 1928, pp. 156, 247-250), and particularly by J. H. Wigner (Ber 36, 796 (1903)). More recent data have been reviewed by Guastalla and Racciu ("Modern Explosives," Industria Chimica 8, 1093-1102 (1933)).

References:[42]

(a) G. C. Hale, Abstract of Available Information on the Preparation and Explosive Properties of Hexanitromannite, PA Special Report No. 238, 30 July 1925.

[42]See footnote 1, page 10.

(b) C. A. Taylor and W. H. Rinkenbach, "Sensitiveness of Detonating Compounds to Frictional Impact, Impact, and Heat," J. Frank Inst 204, 369-76 (1927).

(c) Ph. Naoum, Z ges Schiess - Sprengstoffw (Munich), pp. 181, 229, 267 (27 June 1932).

(d) H. Kast, Z angew Chem, 36, 74 (1923).

(e) A. Schmidt, Z ges Schiess - Sprengstoffw 29, 262, (1934).

Landolt and Börnstein, E III, p. 2914.

(f) A. Marshall, Explosives, Their Manufacture, Properties, Tests, and History, Vol III, London (1932) p. 39. Ph. Naoum, Nitroglycerin and Nitroglycerin Explosives, Baltimore, (1928), pp. 156, 247-250.

(g) A. Schmidt, Z ges Schiess - Sprengstoffw 29, 262 (1934) G. Fleury, L. Brissand and P. Lhoste, "Structure and Stability of Nitric Esters," Comp rend 224, 1016-18 (1947). W. R. Tomlinson, Jr., Fundamental Properties of High Explosives. Thermodynamic Relations for Use in the Estimation of Explosive Properties, PATR No. 1651, 22 April 1947.

(h) Sarran and Vielle, Mém poudr 2, 161 (1884-1889).

(i) E. von Hurtz, U. S. Patent 1,878,652 (20 September 1932).

(j) L. A. Burrows, U. S. Patent 2,427,899 (23 September 1947).

(k) B. T. Fedoroff, Handbook of Explosives and Related Items, Picatinny Arsenal (unpublished).

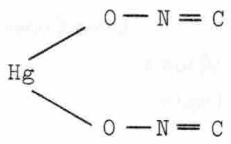
(l) O. E. Sheffield, Literature Survey on Mannitol Hexanitrate, PA Chemical Research Laboratory Report No. 52-TM1-16, 23 January 1952.

(m) Also see the following Picatinny Arsenal Technical Reports on Mannitol Hexanitrate:

| 2 | 4 | 5 | 6 |
|---|---|---|---|
| 1352 | 24<br>64 | 85 | 6 |

**Composition:**

| | % |
|---|---|
| C | 8.4 |
| N | 9.8 |
| O | 11.2 |
| Hg | 70.6 |
| C/H Ratio | |




**Molecular Weight:** ($HgC_2N_2O_2$) 285

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -17 |
| CO % | -5.5 |

**Density:** gm/cc Crystal 4.43

**Melting Point:** °C Decomposes

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm 5; (1 kg wt) | 35 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. 2; (1 lb wt) | 4 |
| Sample Wt, mg | 30 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Explodes |
| Fiber Shoe | Explodes |

**Vacuum Stability Test:**

cc/40 Hrs, at

| | |
|---|---|
| 90°C | |
| 100°C | Explodes |
| 120°C | |
| 135°C | |
| 150°C | |

**Rifle Bullet Impact Test:**

| | Trials | % |
|---|---|---|
| Explosions | | |
| Partials | | |
| Burned | | |
| Unaffected | | |

**200 Gram Bomb Sand Test:**

Sand, gm

Black powder fuse 23.4

**Explosion Temperature:** °C

| Seconds, 0.1 (no cap used) | | 263 |
|---|---|---|
| 1 | | 239 |
| 5 | Explodes | 210 |
| 10 | | 199 |
| 15 | | 194 |
| 20 | | 190 |

**Sensitivity to Initiation:**

Minimum Detonating Charge, gm

Mercury Fulminate

Lead Azide

Tetryl

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:** (a) 51

**75°C International Heat Test:**

% Loss in 48 Hrs 0.18

**Plate Dent Test:**

Method

Condition

Confined

Density, gm/cc

Brisance, % TNT

**100°C Heat Test:** Exploded in 16 hours

% Loss, 1st 48 Hrs

% Loss, 2nd 48 Hrs

Explosion in 100 Hrs

**Detonation Rate:**

| Confinement | | | |
|---|---|---|---|
| Condition | Pressed | | |
| Charge Diameter, in. | | | |
| Density, gm/cc | 2.0 | 3.0 | 4.0 |
| Rate, meters/second | 3500 | 4250 | 5000 |

**Flammability Index:**

**Hygroscopicity:** % 30°C, 90% RH 0.02

**Volatility:**

# Mercury Fulminate

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** White to gray

**Principal Uses:** Detonators and ingredient of priming compositions

**Method of Loading:** psi x $10^3$

| 3 | 5 | 10 | 12 | 15 | 20 |
|---|---|---|---|---|---|
| 3.00 | 3.20 | 3.60 | 3.70 | 3.82 | 4.00 |

**Loading Density:** gm/cc

**Storage:**

| | |
|---|---|
| Method | Wet |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group M (wet) |
| Exudation | None |

Stab Sensitivity:

| Density gm/cc | Firing Point (inch-ounces) 0% | 50% | 100% |
|---|---|---|---|
| 3.91 | 3.2 | 4.3 | 5.5 |
| 4.26 | 1.6 | 2.6 | 5.5 |
| 4.32 | 1.6 | 2.6 | 4.0 |
| 4.50 | 1.6 | 2.5 | 4.0 |

Activation Energy:

| | |
|---|---|
| kcal/mol | 29.81 |
| Induction Period, sec | 0.5-10 |

Heat of:

| | |
|---|---|
| Combustion, cal/gm | 938 |
| Explosion, cal/gm | 427 |
| Gas Volume, cc/gm | 243 |
| Formation, cal/gm | -226 |

Specific Heat: cal/gm/°C 1.1

Thermal Conductivity:
cal/sec/cm/°C $1 \times 10^{-4}$

Initiating Efficiency; Grams Required to Give Complete Initiation of:

| | Fulminate, gm |
|---|---|
| TNT | 0.25 |
| Tetryl | 0.20 |
| RDX | 0.19 |
| PETN | 0.17 |

Compatibility with Metals:

Dry: Reacts rapidly with aluminum and magnesium. Reacts slowly with copper, zinc, brass and bronze. Iron and steel are not affected.

Wet: Reacts immediately with aluminum and magnesium. Reacts rapidly with copper, zinc, brass and bronze. Iron and steel are not affected.

Sensitivity to Static Discharge, Joules: (b) 0.025

The Effect of Storage at 50°C (Dry) on the Purity of Mercury Fulminate

| Months Storage | Recrystallized Lots 979 | 980 | 981 | 982 | Uncrystallized Lots 505.6-7/31 | 505.3-5/11 |
|---|---|---|---|---|---|---|
| 0 | 99.75 | 99.77 | 99.79 | 99.79 | 98.86 | |
| 4 | | | | | | 98.7 |
| 6 | 99.38 | 99.45 | 99.54 | 99.47 | 95.95 | 98.7 |
| 8 | | | | | | 97.4 |
| 9 | | | | | 94.95 | |
| 10 | | | | | | 94.9 |
| 12 | 98.74 | 99.56 | 97.49 | 99.06 | 90.65 | |
| 13 | 98.26 | | | 98.79 | | |
| 14 | 98.22 | | | | | |
| 15 | 97.52 | 99.30 | 99.30 | 98.19 | 83.76 | |
| 16 | 97.00 | | 99.01 | 97.75 | | |
| 17 | 95.70 | 98.66 | | 96.69 | | |
| 18 | 94.81 | 98.58 | 98.46 | 95.90 | | |
| 23 | | | | | 79.99 | |
| 26 | | | | | 74.52 | |
| | | | | | 63.80 | |

Chemistry:

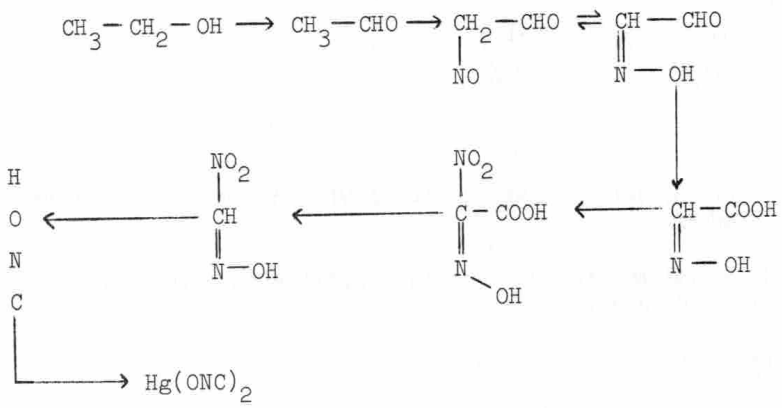
Mercuric fulminate readily decomposes in the presence of aqueous solutions, chlorides, carbonate and many other materials. Due to the presence of small amounts of mercury, formed by exposure to light or elevated temperatures, it readily forms amalgams with copper, brass and bronze, thus components containing these metals must be protectively coated if used with fulminate.

Solubility, Grams of Mercury Fulminate in 100 Grams of Water (%):

| °C | % |
|---|---|
| 12 | 0.07 |
| 49 | 0.18 |

Preparation:

(Chemistry of Powder and Explosives, Davis)



Five gm mercury is dissolved in 25 cc of nitric acid (sp gr 1.42) without agitation, and this solution poured into 50 cc of 90% ethyl alcohol, resulting in a vigorous reaction, attended by evolution of white fumes and subsequent appearance of fulminate crystals. Red fumes then appear as precipitation of the product accelerates, and then white fumes again are evolved as the reaction moderates. After about 20 minutes the reaction is over; water is added, and the crystals are repeatedly washed, by decantation, with water to remove all acidity. The product is purified, rendered white, by solution in strong ammonium hydroxide, followed by reprecipitation with 30% acetic acid.

Origin:

Mercury fulminate was first prepared by John K. von Lowenstern (1630-1703) and in 1800 its preparation and properties were first described in detail by Edward Howard in a paper presented to the Royal Society of London (Phil Trans, 204 (1800). It was 1867 before the compound was used as an initiating agent, when Alfred Nobel invented the blasting cap and used mercury fulminate to detonate nitroglycerin (British Patent 1345 (1867)).

Destruction by Chemical Decomposition:

Mercury fulminate is decomposed by adding it, while stirring, to at least 10 times its weight of 20% sodium thiosulfate. Some poisonous cyanogen gas may be evolved.

References:[43]

(a) Ph. Naoum - Z ges Schiess-Sprengstoffw (Munich), pp. 181, 229, 267 (27 June 1932).

(b) F. W. Brown, D. H. Kusler, and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.

[43]See footnote 1, page 10.

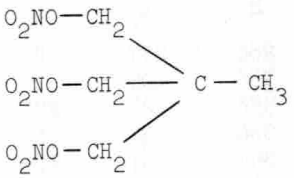
(c) Also see the following Picatinny Arsenal Technical Reports on Mercury Fulminate:

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 250 | 301 | 132 | 23 | 144 | 65 | 266 | 277 | 28 | 199 |
| 480 | 381 | 452 | 203 | 294 | 105 | 366 | 297 | 78 | 609 |
| 510 | 561 | 522 | 393 | 534 | 255 | 556 | 407 | 278 | 749 |
| 550 | 1651 | 582 | 433 | 624 | 285 | 566 | 537 | 318 | 849 |
| 610 | | 782 | 833 | 694 | 365 | 866 | 567 | 788 | 999 |
| 680 | | 882 | 1183 | 784 | 415 | 986 | 637 | 1838 | 1079 |
| 760 | | 932 | 1393 | 874 | 425 | 1316 | 857 | | 1389 |
| 1220 | | 1192 | 2093 | 1104 | 1325 | 1486 | 1737 | | 2179 |
| 1450 | | 1352 | | | 1365 | 1556 | | | |
| | | 1372 | | | | 2146 | | | |
| | | 1722 | | | | | | | |
| | | 2032 | | | | | | | |

 Metriol Trinitrate (MTN) Liquid (or Trimethylolethane Trinitrate)

**Composition:**

| | % |
|---|---|
| C | 23.5 |
| H | 3.5 |
| N | 16.6 |
| O | 56.4 |



C/H Ratio 0.150

**Molecular Weight:** ($C_5H_9N_3O_9$) 255

**Oxygen Balance:**
- $CO_2$ % -35
- CO % - 3

**Density:** gm/cc Liquid 1.47

**Melting Point:** °C -3

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^D$ / $n_{25}^D$ 1.4752 / $n_{30}^D$

**Impact Sensitivity, 2 Kg Wt:**
- Bureau of Mines Apparatus, cm 47; (1 lb wt) 4
  Sample Wt 20 mg
- Picatinny Arsenal Apparatus, in.
  Sample Wt, mg 20

**Friction Pendulum Test:**
- Steel Shoe Explodes
- Fiber Shoe

**Vacuum Stability Test:**
cc/40 Hrs, at
- 90°C
- 100°C cc/gm 1.9
- 120°C
- 135°C
- 150°C

**Rifle Bullet Impact Test:**

| | Trials | % |
|---|---|---|
| Explosions | | |
| Partials | | |
| Burned | | |
| Unaffected | | |

**200 Gram Bomb Sand Test:**
Sand, gm 43.7

**Explosion Temperature:** °C
Seconds, 0.1 (no cap used)
- 1
- 5 Ignites 235
- 10
- 15
- 20

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm
- Mercury Fulminate
- Lead Azide
- Tetryl

**Ballistic Mortar, % TNT:** (a) 136

**Trauzl Test, % TNT:** (b) 140

**75°C International Heat Test:**
% Loss in 48 Hrs

**Plate Dent Test:**
- Method
- Condition
- Confined
- Density, gm/cc
- Brisance, % TNT

**100°C Heat Test:**
- % Loss, 1st 48 Hrs 2.5
- % Loss, 2nd 48 Hrs 1.8
- Explosion in 100 Hrs None

**Detonation Rate:**
- Confinement
- Condition
- Charge Diameter, in.
- Density, gm/cc
- Rate, meters/second

**Flammability Index:**

**Hygroscopicity:** % 30°C, 90% RH 0.07

**Volatility:** 60°C, mg/cm²/hr 24

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**Fragment Velocity:** ft/sec

At 9 ft

At 25½ ft

Density, gm/cc

**Blast (Relative to TNT):**

**Air:**

Peak Pressure

Impulse

Energy

**Air, Confined:**

Impulse

**Under Water:**

Peak Pressure

Impulse

Energy

**Underground:**

Peak Pressure

Impulse

Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Oily, slightly turbid

**Principal Uses:** Ingredient of rocket and double base propellants

**Method of Loading:**

**Loading Density:** gm/cc

**Storage:**

| | |
|---|---|
| Method | Liquid |
| Hazard Class (Quantity-Distance) | |
| Compatibility Group | |
| Exudation | |

| Solubility in Water, gm/100 gm, at: | |
|---|---|
| 25°C | < 0.015 |
| 60°C | < 0.015 |
| **Heat of:** | |
| Combustion, cal/gm | 2642 |
| **Hydrolysis, % Acid:** | |
| 10 days at 22°C | 0.018 |
| 5 days at 60°C | 0.115 |

## Metriol Trinitrate (MTN) Liquid

Preparation:

Metriol (trimethylolmethylmethane) is obtained by the following procedure, based on work by Hosaeus (Annalen 276, 76 (1893):

Into a 5 liter round bottom flask is weighed 2700 gms of water. To this are added 267 gms of 36% formaldehyde and 60 gms of propionaldehyde. The mixture is stirred for a few seconds. To the mixture is added 150 gms of calcium oxide previously slaked with 600 gms of water. The mixture is heated in boiling water for four hours, and then allowed to cool spontaneously overnight. After filtering off the insoluble calcium hydroxide, the solution is heated and treated with a saturated aqueous solution of oxalic acid to precipitate all the calcium. The precipitated calcium oxalate is filtered off, and the pale-yellow filtrate concentrated as much as possible on the steam bath to a thick lemon-yellow syrup. After dissolving in absolute alcohol, the solution is filtered and concentrated in the steam bath to about twice the volume of the concentrated syrup. The solution is then chilled in a cold box to hasten crystallization. After allowing it to warm up to just above 0°C, the mixture is filtered. The resulting product is not sufficiently pure and is recrystallized from absolute alcohol. The melting point of the product (40.3 gm) is then about 196°C (Hosaeus gives 199°C).

Metriol is nitrated by carefully mixing it with 3.5 parts of 65/35 $HNO_3/H_2SO_4$ maintained at 20°C, stirring for 30 minutes, cooling to 5°C, and pouring the reaction mixture on ice. It is extracted with ether, water-washed, and adjusted to pH 7 by shaking with a sodium bicarbonate solution and again water-washed three times. It is then dried with calcium chloride, filtered, and freed of ether by bubbling with dry air until minimal rate of loss in weight is attained. The yield is 88% of the theoretical. The product has a nitrate-nitrogen content of 16.35% (calculated: 16.47%). Its refractive index at 25°C is 1.4752.

Origin:

MTN, according to Italian sources, was first prepared and patented by Bombrini-Parodi-Delfino Company of Italy under the name "metriolo." A German Patent of 1927 also describes the preparation and gives some properties. This compound was known in France before World War II under the name of "Nitropentaglycerin" and Burlot and Thomas determined its heat of combustion (Ref b).

References:[44]

(a) A. H. Blatt, Compilation of Data on Organic Explosives, OSRD Report No. 2014, 29 February 1944.

(b) E. Burlot and M. Thomas, Mém poudr 29, 262 (1939).

(c) Also see the following Picatinny Arsenal Technical Reports on Metriol Trinitrate: 1616 and 1817.

[44]See footnote 1, page 10.

**Composition:**
%

| | |
|---|---|
| Ammonium Nitrate | 40 |
| TNT | 40 |
| Aluminum | 20 |
| C/H Ratio | |

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 35 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 13 |
| Sample Wt, mg | 17 |

**Friction Pendulum Test:**
Steel Shoe
Fiber Shoe

**Rifle Bullet Impact Test:** Trials

%
Explosions
Partials
Burned
Unaffected

**Explosion Temperature:** °C

Seconds, 0.1 (no cap used)
1
5 Ignites 435
10
15
20

**75°C International Heat Test:**
% Loss in 48 Hrs

**100°C Heat Test:**
% Loss, 1st 48 Hrs
% Loss, 2nd 48 Hrs
Explosion in 100 Hrs

**Flammability Index:** 100

**Hygroscopicity:** %

**Volatility:**

**Molecular Weight:** 71

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -38 |
| CO % | -20 |

**Density:** gm/cc 1.62-1.68

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$
$n_{25}^{D}$
$n_{30}^{D}$

**Vacuum Stability Test:**
cc/40 Hrs, at
90°C
100°C
120°C 2.1
135°C
150°C

**200 Gram Bomb Sand Test:**
Sand, gm

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm
Mercury Fulminate
Lead Azide
Tetryl

**Ballistic Mortar, % TNT:** (a) 143

**Trauzl Test, % TNT:** (b) 165

**Plate Dent Test:** (c)

| | |
|---|---|
| Method | B |
| Condition | Pressed |
| Confined | No |
| Density, gm/cc | 1.73 |
| Brisance, % TNT | 66 |

**Detonation Rate:** (d)

| | |
|---|---|
| Confinement | None |
| Condition | Cast |
| Charge Diameter, in. | 1.6 |
| Density, gm/cc | 1.68 |
| Rate, meters/second | 5820 |

Minol-2

| | |
|---|---|
| **Booster Sensitivity Test:** | (e) |
| Condition | Pressed |
| Tetryl, gm | 100 |
| Wax, in. for 50% Detonation | 1.46 |
| Wax, gm | |
| Density, gm/cc | 1.74 |
| **Heat of:** | (f) |
| Combustion, cal/gm | 3160 |
| Explosion, cal/gm | 1620 |
| Gas Volume, cc/gm | |
| Formation, cal/gm | |
| Fusion, cal/gm | |
| **Specific Heat:** cal/gm/°C | |
| At -5°C | 0.30 |
| Density, gm/cc | 1.74 |
| **Burning Rate:** | |
| cm/sec | |
| **Thermal Conductivity:** | (b) |
| cal/sec/cm/°C | $16.5 \times 10^{-4}$ |
| Density, gm/cc | 1.74 |
| **Coefficient of Expansion:** | |
| Linear, %/°C | |
| Volume, %/°C | |
| **Hardness, Mohs' Scale:** | |
| **Young's Modulus:** | (b) |
| E', dynes/cm² | $5.03 \times 10^{10}$ |
| E, lb/inch² | $0.73 \times 10^{6}$ |
| Density, gm/cc | 1.66 |
| **Compressive Strength:** lb/inch² | (b) 1910-2070 |
| Density, gm/cc | 1.68 |
| **Vapor Pressure:** | |
| °C mm Mercury | |

**Decomposition Equation:**

Oxygen, atoms/sec (Z/sec)

Heat, kilocalorie/mole (ΔH, kcal/mol)

Temperature Range, °C

Phase

**Armor Plate Impact Test:** (f)

**60 mm Mortar Projectile:**

50% Inert, Velocity, ft/sec 828

Aluminum Fineness

**500-lb General Purpose Bombs:**

Plate Thickness, inches

1

1¼

1½

1¾

**Bomb Drop Test:**

**T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:**

Max Safe Drop, ft

**500-lb General Purpose Bomb vs Concrete:**

Height, ft

Trials

Unaffected

Low Order

High Order

**1000-lb General Purpose Bomb vs Concrete:**

Height, ft

Trials

Unaffected

Low Order

High Order

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**Fragment Velocity:** ft/sec

At 9 ft

At 25½ ft

Density, gm/cc

**Blast (Relative to TNT):**

| | |
|---|---|
| **Air:** | |
| Peak Pressure | 115 |
| Impulse | 116 |
| Energy | 133 |
| **Air, Confined:** | |
| Impulse | 90 |
| **Under Water:** | |
| Peak Pressure | 108 |
| Impulse | 126 |
| Energy | 140 |
| **Underground:** | |
| Peak Pressure | 134 |
| Impulse | 139 |
| Energy | 147 |

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Gray

**Principal Uses:** Bombs and depth charges

**Method of Loading:** Cast

**Loading Density:** gm/cc 1.62-1.68

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | |

Preparation:

Minol is a castable mixture consisting of 40 percent TNT, 40 percent ammonium nitrate, and 20 percent powdered aluminum and therefore can be prepared by adding the dry ingredients to molten TNT at 90°C under agitation. Minol also can be prepared by adding 25 parts of aluminum to 100 parts of 50/50 amatol previously prepared.

## Minol-2

Origin:

Minols are British ternary explosives developed during World War II. There are three formulations:

| Composition, %: | Minol-1 | Minol-2 | Minol-3 |
|---|---|---|---|
| TNT | 48 | 40 | 42 |
| Ammonium Nitrate | 42 | 40 | 38 |
| Aluminum | 10 | 20 | 20 |

References:[45]

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.

(c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(d) G. H. Messerly, The Rate of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.

M. D. Hurwitz, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1946.

(e) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

(f) Committee of Div 2 and 8, NDRC, Report on HBX and Tritonal, OSRD No. 5406, 31 July 1945.

(g) W. R. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Technical Div Lecture, 9 April 1948.

(h) Also see the following Picatinny Arsenal Technical Reports on Minol-2: 1585 and 1635.

[45]See footnote 1, page 10.

**Composition:**

| | % |
|---|---|
| Oxidizing agent (Ammonium Perchlorate) | 35.0 |
| Aluminum, atomized | 26.2 |
| Cupric Oxide | ---- |
| Magnesium, atomized | 26.2 |
| Other ingredient (Tetryl) | 9.7 |
| Calcium Stearate | 1.9 |
| Graphite, artificial | 1.0 |
| C/H Ratio | |

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | -- |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 13 |
| Sample Wt, mg | 22 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Detonates |
| Fiber Shoe | Unaffected |

**Rifle Bullet Impact Test:**

| | Trials | % |
|---|---|---|
| Explosions | | |
| Partials | | |
| Burned | | |
| Unaffected | | |

**Explosion Temperature:** °C

| Seconds, 0.1 (no cap used) | --- |
|---|---|
| 1 | --- |
| 5 | 285 |
| 10 | |
| 15 | |
| 20 | |

**75°C International Heat Test:**

| | |
|---|---|
| % Loss in 48 Hrs | |
| Discoloration, fumes, odor | None |

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.10 |
| % Loss, 2nd 48 Hrs | 0.01 |
| Explosion in 100 Hrs | None |

**Flammability Index:**

**Hygroscopicity:** %

**Volatility:**

**Molecular Weight:** 40.6

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -44 |
| CO % | -37 |

**Density:** gm/cc Pressed 2.0

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Vacuum Stability Test:**

| cc/40 Hrs, at | |
|---|---|
| 90°C | ---- |
| 100°C | 0.47 |
| 120°C | |
| 135°C | |
| 150°C | |

**200 Gram Bomb Sand Test:**

| | |
|---|---|
| Sand, gm | 10.6 |

**Sensitivity to Initiation:**

| Minimum Detonating Charge, gm | |
|---|---|
| Mercury Fulminate | ---- |
| Lead Azide | 0.20 |
| Tetryl | 0.25 |

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**Plate Dent Test:**

Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**Detonation Rate:**

Confinement
Condition
Charge Diameter, in.
Density, gm/cc
Rate, meters/second

MOX-1

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**Fragment Velocity:** ft/sec

At 9 ft

At 25½ ft

Density, gm/cc

**Blast (Relative to TNT):**

**Air:**

Peak Pressure

Impulse

Energy

**Air, Confined:**

Impulse

**Under Water:**

Peak Pressure

Impulse

Energy

**Underground:**

Peak Pressure

Impulse

Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Gray powder mixture

**Principal Uses:** Small caliber antiaircraft projectiles

**Method of Loading:** Pressed

**Loading Density:** gm/cc

At 30,000 psi ~ 2.0

**Storage:**

Method: Dry

Hazard Class (Quantity-Distance): Class 9

Compatibility Group: Group I

Bureau of Explosives Classification: Class A

Exudation

Heat of:

| | |
|---|---|
| Combustion, cal/gm | 4087 |
| Explosion, cal/gm | 2087 |
| Gas volume, cc/gm | 212 |

Performance Tests:

20 mm T215E1 Projectile:

| | |
|---|---|
| NFOC Pressure Cube | 35 |
| APG Blast Cube | 40 |

Activation Energy:

| | |
|---|---|
| kcal/mol | 12.5 |
| Temp, °C | 300 to 380 |
| Time to ignition, seconds | $1.78 \times 10^{-4}$ |

**Composition:**

| | % |
|---|---|
| Oxidizing agent (Ammonium Perchlorate) | 35.0 |
| Aluminum, atomized | 52.4 |
| Cupric Oxide | ---- |
| Magnesium, atomized | ---- |
| Other ingredients* | 9.7 |
| Calcium Stearate | 1.9 |
| Graphite, artificial | 1.0 |

*5.8% RDX and 3.9% TNT coated on Ammonium Perchlorate.

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | -- |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 12 |
| Sample Wt, mg | 24 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | Unaffected |

**Rifle Bullet Impact Test:**

| | Trials | % |
|---|---|---|
| Explosions | | |
| Partials | | |
| Burned | | |
| Unaffected | | |

**Explosion Temperature:**

| Seconds, 0.1 (no cap used) | °C |
|---|---|
| 1 | --- |
| 5 | 375 |
| 10 | |
| 15 | |
| 20 | |

**75°C International Heat Test:**

| | |
|---|---|
| % Loss in 48 Hrs | |
| Discoloration, fumes, odor | None |

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.27 |
| % Loss, 2nd 48 Hrs | 0.12 |
| Explosion in 100 Hrs | None |

**Flammability Index:**

**Hygroscopicity:** %

**Volatility:**

**Molecular Weight:** 42

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -49 |
| CO % | -43 |

**Density:** gm/cc Pressed 2.0

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Vacuum Stability Test:**

| cc/40 Hrs, at | |
|---|---|
| 90°C | ---- |
| 100°C | 0.21 |
| 120°C | |
| 135°C | |
| 150°C | |

**200 Gram Bomb Sand Test:**

| | |
|---|---|
| Sand, gm | 11.5 |

**Sensitivity to Initiation:**

| Minimum Detonating Charge, gm | |
|---|---|
| Mercury Fulminate | ---- |
| Lead Azide | 0.20 |
| Tetryl | 0.20 |

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**Plate Dent Test:**

Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**Detonation Rate:**

Confinement
Condition
Charge Diameter, in.
Density, gm/cc
Rate, meters/second

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**Fragment Velocity:** ft/sec

At 9 ft

At 25½ ft

Density, gm/cc

**Blast (Relative to TNT):**

| | EW* | EV* |
|---|---|---|
| **Air:** Bare Charge: | | |
| Peak Pressure | 1.02 | 1.34 |
| Impulse | 1.08 | 1.41 |
| Energy Density, gm/cc | | 1.96 |
| **Air, Confined:** Impulse | | |
| Cased Charge in Air:** | | |
| Peak Pressure | 1.09 | 1.44 |
| Impulse | 1.16 | 1.53 |
| Energy | ---- | ---- |
| Density, gm/cc | | 1.98 |
| **Underground:** Peak Pressure | | |
| Impulse | | |
| Energy | | |

*EW, equivalent weight as compared to TNT; EV, equivalent volume as compared to TNT.

**Strong paper-base phenolic case.

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Gray

**Principal Uses:** HE filler for small caliber projectiles

**Method of Loading:** Pressed

**Loading Density:** gm/cc 2.0

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group Bureau of Explosives Class A | Group I |
| Exudation | None |

Heat of:

| | |
|---|---|
| Combustion, cal/gm | 4484 |
| Explosion, cal/gm | 1472 |
| Gas volume, cc/gm | 221 |

Performance Tests:

20 mm T215E1 Projectile:

| | |
|---|---|
| NFOC Pressure Cube | 29 |
| APG Blast Cube | 30 |

Aviation Energy:

| | |
|---|---|
| kcal/mol | 7.6 |
| Temp, °C | 340 to 470 |
| Time to ignition, seconds | $1.39 \times 10^{-2}$ |

Effect of Altitude, Charge Diameter and Degree of Confinement on Detonation Velocity* (Reference g)

| Simulated Altitude, Feet | One-Inch Column | | Two-Inch Column | |
|---|---|---|---|---|
| | Confined m/s | Unconfined m/s | Confined m/s | Unconfined m/s |
| Ground | Charge would not propagate detonation. | | 4730 | Charge would not propagate detonation. |
| 30,000 | | | 4530(3) | |
| 60,000 | | | 4430 | |
| 90,000 | | | 4290 | |
| Average | | | 4495 | |

*Confined charge in 1/4" steel tube, AISI 1015 seamless, 1" diameter 18" long, and 2" diameter 7" long. All means were determined from sets of five values unless otherwise indicated by ( ). A 26 gm tetryl booster was used to initiate each charge.

Average Fragment Velocity at Various Altitudes* (g)

| Explosive | Charge Diameter, Inches | Simulated Altitude, Feet | | | |
|---|---|---|---|---|---|
| | | Ground m/s | 30,000 m/s | 60,000 m/s | 90,000 m/s |
| MOX-2B, density, gm/cc 207 | 1 | 2012 | ** | ** | ** |
| | 2 | 3314 | 3351 | 3247 | ** |

*Outside diameter 2.54"; inside diameter 2.04"; length 7".

**Charge would not propagate detonation.

MOX-3B

**Composition:**

| | % |
|---|---|
| Oxidizing agent (Potassium Nitrate) | 18 |
| Aluminum, atomized | 50 |
| Cupric Oxide | -- |
| Magnesium, atomized | -- |
| Other ingredients* | 32 |
| Calcium Stearate** | 2.0 |
| Graphite, artificial** | 1.0 |

*29.1% RDX, 0.9% wax, and 2.0% TNT.
**Per cent added.

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | -- |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 17 |
| Sample Wt, mg | 24 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | Unaffected |

**Rifle Bullet Impact Test:**

| | Trials | % |
|---|---|---|
| Explosions | | |
| Partials | | |
| Burned | | |
| Unaffected | | |

**Explosion Temperature:** °C

| Seconds, 0.1 (no cap used) | --- |
|---|---|
| 1 | --- |
| 5 | 540 |
| 10 | |
| 15 | |
| 20 | |

**75°C International Heat Test:**
% Loss in 48 Hrs
Discoloration, fumes, odor: None

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.35 |
| % Loss, 2nd 48 Hrs | 0.13 |
| Explosion in 100 Hrs | None |

**Flammability Index:**

**Hygroscopicity:** %

**Volatility:**

**Molecular Weight:** 45.6

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -52 |
| CO % | -43 |

**Density:** gm/cc — Pressed: 2.0

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Vacuum Stability Test:**
cc/40 Hrs, at

| | |
|---|---|
| 90°C | ---- |
| 100°C | 0.57 |
| 120°C | |
| 135°C | |
| 150°C | |

**200 Gram Bomb Sand Test:**
Sand, gm: 33.2

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | ---- |
| Lead Azide | 0.20 |
| Tetryl | 0.15 |

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**Plate Dent Test:**
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**Detonation Rate:**
Confinement
Condition
Charge Diameter, in.
Density, gm/cc
Rate, meters/second

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**Fragment Velocity:** ft/sec

At 9 ft

At 25½ ft

Density, gm/cc

**Blast (Relative to TNT):**

**Air:**

Peak Pressure

Impulse

Energy

**Air, Confined:**

Impulse

**Under Water:**

Peak Pressure

Impulse

Energy

**Underground:**

Peak Pressure

Impulse

Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Gray powder mixture

**Principal Uses:** Small caliber antiaircraft projectiles

**Method of Loading:** Pressed

**Loading Density:** gm/cc

At 30,000 psi ~2.0

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| | Bureau of Explosives Class A |

Heat of:

| | |
|---|---|
| Combustion, cal/gm | 4331 |
| Explosion, cal/gm | 980 |
| Gas volume, cc/gm | 232 |

Performance Tests:

20 mm T215E1 Projectile:

| | |
|---|---|
| NFOC Pressure Cube | 37 |
| APG Blast Cube | 52 |

Activation Energy:

| | |
|---|---|
| kcal/mol | Values not included due to erratic ignition under conditions of test. |
| Temp, °C | |
| Time to ignition, seconds | |

MOX-4B

**Composition:**

| | % |
|---|---|
| Oxidizing agent (Barium Nitrate) | 18 |
| Aluminum, atomized | 50 |
| Cupric Oxide | -- |
| Magnesium, atomized | -- |
| Other ingredients* | 32 |
| Calcium Stearate** | 2.0 |
| Graphite, artificial** | 1.0 |

*29.1% RDX, 0.9% wax, and 2.0% TNT.
**Per cent added.

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 78 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 18 |
| Sample Wt, mg | 26 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Sparks |
| Fiber Shoe | Unaffected |

**Rifle Bullet Impact Test:**

| | Trials | % |
|---|---|---|
| Explosions | | |
| Partials | | |
| Burned | | |
| Unaffected | | |

**Explosion Temperature:** °C

| Seconds, 0.1 (no cap used) | --- |
|---|---|
| 1 | --- |
| 5 | 610 |
| 10 | |
| 15 | |
| 20 | |

**75°C International Heat Test:**
% Loss in 48 Hrs
Discoloration, fumes, odor: None

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.22 |
| % Loss, 2nd 48 Hrs | 0.12 |
| Explosion in 100 Hrs | None |

**Flammability Index:**

**Hygroscopicity:** %

**Volatility:**

**Molecular Weight:** 48

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -53 |
| CO % | -43 |

**Density:** gm/cc — Pressed: 2.0

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Vacuum Stability Test:**
cc/40 Hrs, at

| | |
|---|---|
| 90°C | ---- |
| 100°C | 0.67 |
| 120°C | |
| 135°C | |
| 150°C | |

**200 Gram Bomb Sand Test:**

| | |
|---|---|
| Sand, gm | 33.6 |

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | ---- |
| Lead Azide | 0.20 |
| Tetryl | 0.15 |

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**Plate Dent Test:**
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**Detonation Rate:**
Confinement
Condition
Charge Diameter, in.
Density, gm/cc
Rate, meters/second

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Gray powder mixture

**Principal Uses:** Small caliber antiaircraft projectiles

**Method of Loading:** Pressed

**Loading Density:** gm/cc
At 30,000 psi ~2.0

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| | Bureau of Explosives |
| | Class A |

Heat of:

| | |
|---|---|
| Combustion, cal/gm | 4392 |
| Explosion, cal/gm | 709 |
| Gas volume, cc/gm | 208 |

Performance Tests:
20 mm T215E1 Projectile:

| | |
|---|---|
| NFOC Pressure Cube | 43 |
| APG Blast Cube | 53 |

Aviation Energy:

| | |
|---|---|
| kcal/mol | Values not included due to erratic ignition under conditions of test. |
| Temp, °C | |
| Time to ignition, seconds | |

MOX-6B

**Composition:**

| | % |
|---|---|
| Oxidizing agent | ---- |
| Aluminum, atomized | 49.2 |
| Cupric Oxide | 19.7 |
| Magnesium, atomized | ---- |
| Other ingredients* | 29.6 |
| Calcium Stearate | ---- |
| Graphite, artificial | 1.5 |

*28.7% RDX coated, 0.9% wax.

C/H Ratio

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 78 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 19 |
| Sample Wt, mg | 27 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | Unaffected |

**Rifle Bullet Impact Test:**

| | Trials | % |
|---|---|---|
| Explosions | | |
| Partials | | |
| Burned | | |
| Unaffected | | |

**Explosion Temperature:** °C

| Seconds, 0.1 (no cap used) | --- |
|---|---|
| 1 | --- |
| 5 | 510 |
| 10 | |
| 15 | |
| 20 | |

**75°C International Heat Test:**

| | |
|---|---|
| % Loss in 48 Hrs | 0.02/10 gm |
| Discoloration, fumes, odor | None |

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.00 |
| % Loss, 2nd 48 Hrs | 0.00 |
| Explosion in 100 Hrs | None |

**Flammability Index:**

**Hygroscopicity:** %

| | |
|---|---|
| 30°C, 90% RH, two weeks | 0.79 |

**Volatility:**

**Molecular Weight:** 43

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -50 |
| CO % | -42 |

**Density:** gm/cc

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Vacuum Stability Test:**

| cc/40 Hrs, at | |
|---|---|
| 90°C | ---- |
| 100°C | 0.43 |
| 120°C | |
| 135°C | |
| 150°C | |

**200 Gram Bomb Sand Test:**

| | |
|---|---|
| Sand, gm | 10.8 |

**Sensitivity to Initiation:**

| Minimum Detonating Charge, gm | |
|---|---|
| Mercury Fulminate | ---- |
| Lead Azide | 0.20 |
| Tetryl | 0.16 |

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**Plate Dent Test:**

Method

Condition

Confined

Density, gm/cc

Brisance, % TNT

**Detonation Rate:**

Confinement

Condition

Charge Diameter, in.

Density, gm/cc

Rate, meters/second

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Gray powder mixture

**Principal Uses:** Small caliber antiaircraft projectiles

**Method of Loading:** Pressed

**Loading Density:** gm/cc
At 30,000 psi ~2.0

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| | Bureau of Explosives Class A |

Heat of:

| | |
|---|---|
| Combustion, cal/gm | 4293 |
| Explosion, cal/gm | 750 |
| Gas volume, cc/gm | 204 |

Activation Energy:

| | |
|---|---|
| kcal/mol | Values not included due to erratic ignition under conditions of test. |
| Temp, °C | |
| Time to ignition, seconds | |

MOX-1; MOX-2B; MOX-3B; MOX-4B; MOX-6B

Preparation:

The various ingredients used in the preparation of MOX explosives are coated separately as follows:

Dichromated Atomized Aluminum - Seventy-five grams of chemically pure grade sodium dichromate is dissolved in 1500 milliliters of water at 100°C under mechanical agitation. Six hundred grams of the atomized aluminum powder is added gradually (2 to 3 minutes) and stirring is continued for half an hour. The dichromated metal is filtered, washed with water (15 to 20 times) until the washings show only a slight cloudiness with silver nitrate. The water-wet product is then dried in an oven at 50°C. The dried material is hand-rolled to reduce any conglomerates, and blended before use.

Wax-Coated RDX - Eighteen grams of molten Be Square Special Wax (manufacturer's 180° to 185° Fahrenheit grade amber) is added to 582 grams of finely divided RDX (water precipitated from acetone solution) in a water slurry under mechanical agitation. The temperature of the wax-RDX slurry is maintained above the melting point of the wax (about 90°C). The stirring is continued for half an hour. After cooling to 50°C, the wax-coated RDX is recovered by filtration in a Büchner funnel and dried in air. The RDX thus coated and presumed to be 3% waxed RDX or a 97/3 RDX/wax mixture is hand-rolled to crush any conglomerates formed, and blended by hand before use.

TNT-Coated Barium Nitrate - Thirty grams of TNT in alcohol solution is added to 270 grams of barium nitrate in an alcohol slurry under agitation. The temperature of the TNT-barium nitrate mixture is maintained at 80°C and stirring is continued until most of the alcohol is evaporated. The coated material is spread in a thin layer on a tray to dry in air overnight. The barium nitrate thus coated with 10% TNT is reduced to an intimate mixture by hand-rolling and blending before use.

TNT-Coated Potassium Nitrate - The TNT-coated potassium nitrate is prepared by the same procedure as is used for coating barium nitrate.

RDX/TNT-Coated Ammonium Perchlorate - The ammonium perchlorate is coated by dissolving the appropriate weights of RDX and TNT in hot alcohol. After adding the ammonium perchlorate, the slurry is stirred until most of the solvent is evaporated. The treated ammonium perchlorate is spread on a tray to dry overnight. Agglomerates formed during the process are crushed by hand-rolling and blending the mixture before use.

TNT-Coated RDX - Sixty grams of molten TNT are added to a water slurry of 540 grams of finely divided RDX (water precipitated from acetone solution) under mechanical agitation. The temperature of the TNT-RDX slurry is maintained at about 90°C and stirring is continued for half an hour. After cooling to about 50°C, the TNT-coated RDX is recovered by filtration. The RDX thus treated, and presumed to be 10% coated or a 90/10 RDX/TNT mixture, is further blended by hand after rolling to crush any aggregates formed during the process.

The MOX explosive mixtures are prepared by blending the appropriate weights of the dry ingredients in a Patterson-Kelly twin-shell blender for at least 30 minutes.

Origin:

MOX type explosive mixtures were developed beginning in 1950 by National Northern, technical division of the National Fireworks Ordnance Corporation, West Hanover, Massachusetts.

References:[46]

(a) A. O. Mirarchi and A. T. Wilson, Development of MOX Explosives for Improved 20 mm Ammunition, Navy Contract NOrd-10975, Task 1, National Fireworks Ordnance Corporation, First Yearly Summary, August 1950 to August 1951.

(b) A. T. Wilson, Development of MOX Explosives: Various Oxidants in MOX, First Progress Report NFOC-6, Navy Contract NOrd-12382, National Fireworks Ordnance Corporation, December 1952.

(c) A. O. Mirarchi, Properties of Explosives: Theory of the MOX Explosion, First Progress Report NFOC-10, Navy Contract NOrd-11393, National Fireworks Ordnance Corporation, December 1952.

(d) A. O. Mirarchi, Properties of Explosives: MOX Explosives in Various Atmospheres, First Progress Report NFOC-9, Navy Contract NOrd-11393, National Fireworks Ordnance Corporation, 1952.

(e) A. T. Wilson, Development of MOX Explosives: Composition Variations, First Progress Report NFOC-7, Navy Contract NOrd-12382, National Fireworks Ordnance Corporation, 1952.

(f) A. T. Wilson, Development of MOX Explosives: Various Oxidants in MOX, Second Progress Report NFOC-14, Navy Contract NOrd-13684, National Fireworks Ordnance Corporation, October 1953.

(g) A. W. O'Brien, Jr., C. W. Plummer, R. P. Woodburn and V. Philipchuk, Detonation Velocity Determinations and Fragment Velocity Determinations of Varied Explosive Systems and Conditions, National Northern Corporation Final Summary Report NNC-F-13, February 1958 (Contract DAI-19-020-501-ORD-(P)-58).

(h) P. Z. Kalanski, Air Blast Evaluation of MOX-2B Cased and Bare Charges, NAVORD Report No. 3755, 5 April 1956.

(i) Also see the following Picatinny Arsenal Technical Reports on MOX Explosives: 1935, 1969, 2204, 2205.

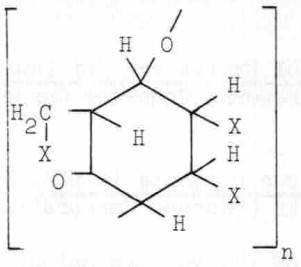
[46] See footnote 1, page 10.

# Nitrocellulose, 12.6% N (NC)

**Composition:**

| | % |
|---|---|
| C | 26.46 |
| H | 2.78 |
| N | 12.60 |
| O | 58.16 |

X=$ONO_2$



C/H Ratio 0.23

**Molecular Weight:** $(272.39)_n$

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -35 |
| CO % | 0.6 |

**Density:** gm/cc

**Melting Point:** °C — Decomposes

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 8 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 3 |
| Sample Wt, mg | 5 |

**Friction Pendulum Test:**

Steel Shoe

Fiber Shoe

**Vacuum Stability Test:**

cc/40 Hrs, at

| | | |
|---|---|---|
| 90°C | | 0.17 |
| 100°C | | 1.0 |
| 120°C | 16 hours | 11.+ |
| 135°C | | |
| 150°C | | |

**Rifle Bullet Impact Test:** Trials

| | % |
|---|---|
| Explosions | |
| Partials | |
| Burned | |
| Unaffected | |

**200 Gram Bomb Sand Test:**

Sand, gm 45.0

**Explosion Temperature:** °C

Seconds, 0.1 (no cap used)

| | | |
|---|---|---|
| 1 | | |
| 5 | Decomposes | 170 |
| 10 | | |
| 15 | | |
| 20 | | |

**Sensitivity to Initiation:**

Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | |
| Lead Azide | 0.10 |
| Tetryl | |

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**75°C International Heat Test:**

% Loss in 48 Hrs

**Plate Dent Test:**

Method

Condition

Confined

Density, gm/cc

Brisance, % TNT

**100°C Heat Test:**

% Loss, 1st 48 Hrs

% Loss, 2nd 48 Hrs

Explosion in 100 Hrs

**Detonation Rate:**

Confinement

Condition

Charge Diameter, in.

Density, gm/cc

Rate, meters/second

**Flammability Index:**

**Hygroscopicity:** % 30°C, 90% RH 3

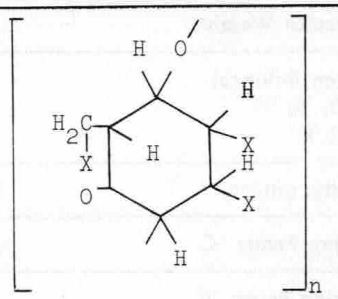
**Volatility:** 60°C, $mg/cm^2/hr$ 0.0

# Nitrocellulose, 13.45% N (NC)

**Composition:**

| | % |
|---|---|
| C | 25.29 |
| H | 2.52 |
| N | 13.45 |
| O | 58.74 |

X=$ONO_2$



C/H Ratio 0.23

**Molecular Weight:** $(286.34)_n$

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -29 |
| CO % | 4.7 |

**Density:** gm/cc

**Melting Point:** °C — Decomposes

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 9 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 3 |
| Sample Wt, mg | 5 |

**Friction Pendulum Test:**

Steel Shoe

Fiber Shoe

**Vacuum Stability Test:**

| cc/40 Hrs, at | |
|---|---|
| 90°C | 0.42 |
| 100°C | 1.5 |
| 120°C | 11.+ |
| 135°C | |
| 150°C | |

**Rifle Bullet Impact Test:**

| | Trials | % |
|---|---|---|
| Explosions | | |
| Partials | | |
| Burned | | |
| Unaffected | | |

**200 Gram Bomb Sand Test:**

Sand, gm — 49.0

**Explosion Temperature:** °C

Seconds, 0.1 (no cap used)

| | |
|---|---|
| 1 | |
| 5 | 230 |
| 10 | |
| 15 | |
| 20 | |

**Sensitivity to Initiation:**

Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | |
| Lead Azide | 0.10 |
| Tetryl | |

**Ballistic Mortar, % TNT:** 125

**Trauzl Test, % TNT:**

**75°C International Heat Test:**

% Loss in 48 Hrs

**Plate Dent Test:**

Method

Condition

Confined

Density, gm/cc

Brisance, % TNT

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.3 |
| % Loss, 2nd 48 Hrs | 0.0 |
| Explosion in 100 Hrs | None |

**Detonation Rate:**

Confinement

Condition

Charge Diameter, in.

| | |
|---|---|
| Density, gm/cc | 1.20 |
| Rate, meters/second | 7300 |

**Flammability Index:**

**Hygroscopicity:** % 30°C, 90% RH ~ 2

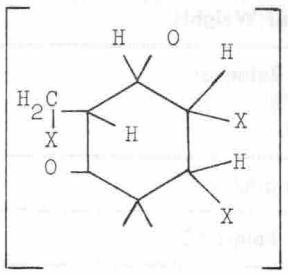
**Volatility:** 60°C, $mg/cm^2/hr$ 0.0

# Nitrocellulose, 14.14% N (NC)

**Composition:**

| | % |
|---|---|
| C | 24.25 |
| H | 2.37 |
| N | 14.14 |
| O | 59.24 |

X=$ONO_2$



C/H Ratio 0.23

**Molecular Weight:** $(297.15)_n$

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -24 |
| CO % | 8 |

**Density:** gm/cc 1.65-1.70

**Melting Point:** °C Decomposes

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 8 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 3 |
| Sample Wt, mg | 5 |

**Friction Pendulum Test:**

Steel Shoe

Fiber Shoe

**Vacuum Stability Test:**

cc/40 Hrs, at

| | | |
|---|---|---|
| 90°C | | 1.46 |
| 100°C | 14 hours | 11.+ |
| 120°C | 16 hours | 11.+ |
| 135°C | | |
| 150°C | | |

**Rifle Bullet Impact Test:** Trials

%

Explosions

Partials

Burned

Unaffected

**200 Gram Bomb Sand Test:**

Sand, gm 52.3

**Explosion Temperature:** °C

Seconds, 0.1 (no cap used)

1

5

10

15

20

**Sensitivity to Initiation:**

Minimum Detonating Charge, gm

Mercury Fulminate

Lead Azide 0.10

Tetryl

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**75°C International Heat Test:**

% Loss in 48 Hrs

**Plate Dent Test:**

Method

Condition

Confined

Density, gm/cc

Brisance, % TNT

**100°C Heat Test:**

% Loss, 1st 48 Hrs

% Loss, 2nd 48 Hrs

Explosion in 100 Hrs

**Detonation Rate:**

Confinement

Condition

Charge Diameter, in.

Density, gm/cc

Rate, meters/second

**Flammability Index:**

**Hygroscopicity:** % 30°C, 90% RH ~ 1

**Volatility:** 60°C, $mg/cm^2/hr$ 0.0

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** White

**Principal Uses:** Pyroxylin (12% N), blasting explosives; pyrocellulose (12.60% N), smokeless powder; guncotton (13.35% N minimum), propellants

**Method of Loading:**

**Loading Density:** gm/cc

**Storage:**

| | |
|---|---|
| Method | Wet (8% to 30% water) |
| Hazard Class (Quantity-Distance) | Class 12 |
| Compatibility Group | Group M (wet) |
| Exudation | None |

Heat of:

| | | | |
|---|---|---|---|
| Combustion, cal/gm | 2409* | 2313** | 2228*** |
| Explosion, cal/gm | 855* | 965** | 1058*** |
| Gas Volume, cc/gm | 919* | 883** | 853*** |
| Formation, cal/gm | 617* | 561** | 513*** |

* 12.6% N
** 13.45% N
*** 14.14% N

Vapor Pressure:

| °C | mm Mercury |
|---|---|
| 25 | 0.00 |
| 60 | 0.00 |

| Solubility in Water, gm/100 gm, at: | 12.6% N | 13.45% N | 14.0% N |
|---|---|---|---|
| 25°C | Insoluble | Insoluble | Insoluble |
| 60°C | Insoluble | Insoluble | Insoluble |
| **Solubility, gm/100 gm, 25°C, in:** | | | |
| Ether | Insoluble | Insoluble | Insoluble |
| Alcohol | Very slightly soluble | Practically insoluble | Insoluble |
| 2:1-Ether:Alcohol | Soluble | Slightly soluble (6%-11%) | Practically insoluble (1 + %) |
| Acetone | Soluble | Soluble | Soluble |
| 240-Hour Hydrolysis Test, % Nitric Acid | 1.22 | 1.03 | |

Preparation of Nitrocellulose from Cotton Linters:
(Laboratory Procedure)

Nitration: Second cut cotton linters, previously dried to a moisture content of less than 0.5%, are nitrated by immersion in mixed acid under the following conditions:

Ratio of Mixed Acid to cotton 55 to 1

Composition of Mixed Acid (approximate)

a. for 12.6% N: $H_2SO_4$ 63.5%, $HNO_3$ 21%, $H_2O$ 15.5%

b. for 13.4% N: $H_2SO_4$ 68%, $HNO_3$ 22%, $H_2O$ 10.0%

Temperature of acid at the start 34°C

Time of nitration 24 minutes

During the nitration period the mixture is turned over occasionally to keep the acid homogeneous. The mixture is then filtered on a Buchner funnel with suction for about three minutes and then drowned rapidly with strong hand stirring in at least 50 volumes of cold water. After the nitrocellulose has settled, most of the water is decanted and fresh water added. The nitrocellulose-water mixture is boiled and the acidity adjusted to 0.25% to 0.50% as $H_2SO_4$. The sour boil is continued for at least 24 hours for pyrocellulose and at least 40 hours for gun-cotton. Additional boiling with changes of water are made in accordance with the governing specification (JAN-N-244).

Pulping: The nitrocellulose is then pulped in a laboratory Holland-type paper beater. Enough sodium carbonate is added to keep the reaction faintly alkaline to phenolphthalein. Pulping is continued to the desired degree of fineness.

Poaching: After washing the nitrocellulose from the beater, the mixture is filtered and the product boiled for 4 hours with fresh water while stirring mechanically. From time to time a little sodium carbonate solution is added to maintain the mixture faintly alkaline to phenolphthalein. The water is decanted and the boiling continued. According to the specification, the total boiling treatment with poaching is as follows:

4 hours boiling with or without sodium carbonate

2 hours boiling without sodium carbonate

1 hour boiling without sodium carbonate

1 hour boiling without sodium carbonate.

Each boil is followed by settling and change of water.

Washing: The nitrocellulose is then washed by mechanical agitation with water. A minimum of two washes are given. If a sample taken after the water washes gives a minimum test of 35 minutes in the 65.5°C Heat Test and 30 minutes in the 134.5°C Heat Test, the nitrocellulose is satisfactorily stabilized. Otherwise additional washes should be given.

Origin:

Cellulose occurs in nature. It is wood fiber, cell wall and the structural material of all plants. Cotton fiber is pure cellulose. Nitrocellulose was discovered about 1847 by C. F. Schonbein at Basel and R. Bottger at Frankfort-on-the-Main independently of each other when cotton was nitrated. T. J. Pelouze had nitrated paper earlier (1838) and was probably the first to prepare nitrocellulose.

Pyroxylin or collodion, which is soluble in a mixture of ether and ethanol, contains from 8% to 12% nitrogen. It is used in the manufacture of celluloid and in composite blasting explosives.

Pyrocellulose, a type of nitrocellulose of 12.6% nitrogen content, completely soluble in a mixture of 2 parts ether and one part ethanol, was developed by Mendeleev (1891-1895). This material, when colloided, formed the first smokeless powder for military use in the United States (1898).

Guncotton for military purposes today contains a minimum of 13.35% nitrogen. It is only slightly soluble in ether-ethanol, but completely soluble in acetone. Principal use is in flashless powders and as flame carriers. 14.14% N nitrocellulose represents a theoretical limit.

In the manufacture of propellants, there is used a mixture of pyrocellulose and guncotton (blended nitrocellulose) of 13.15% to 13.25% nitrogen content.

Destruction by Chemical Decomposition:

Nitrocellulose is decomposed by adding it, with stirring, to 5 times its weight of 10% sodium hydroxide heated to 70°C. Stirring is continued for 15 minutes after all the nitrocellulose has been added.

References:[47]

(a) See the following Picatinny Arsenal Technical Reports on Nitrocellulose:

[47]See footnote 1, page 10.

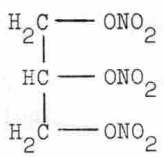
Nitrocellulose (NC)

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 10 | 41 | 72 | 13 | 4 | 125 | 86 | 167 | 8 | 19 |
| 390 | 101 | 332 | 33 | 24 | 475 | 576 | 327 | 198 | 29 |
| 420 | 231 | 402 | 43 | 114 | 485 | 586 | 407 | 208 | 69 |
| 660 | 351 | 422 | 133 | 174 | 495 | 796 | 717 | 278 | 169 |
| 730 | 551 | 542 | 233 | 194 | 555 | 916 | 787 | 388 | 279 |
| 960 | 831 | 572 | 253 | 334 | 705 | 1016 | 987 | 408 | 499 |
| 1020 | 851 | 652 | 273 | 374 | 965 | 1026 | 1187 | 588 | 659 |
| 1100 | 971 | 662 | 653 | 394 | 1065 | 1066 | 1197 | 718 | 669 |
| 1150 | 1031 | 752 | 673 | 724 | 1125 | 1206 | 1267 | 758 | 709 |
| 1190 | 1041 | 802 | 683 | 804 | 1135 | 1256 | 1297 | 778 | 739 |
| 1210 | 1071 | 952 | 773 | 894 | 1205 | 1276 | 1327 | 808 | 779 |
| 1240 | 1151 | 1012 | 793 | 1024 | 1265 | 1306 | 1407 | 838 | 809 |
| 1300 | 1201 | 1032 | 963 | 1054 | 1275 | 1316 | 1427 | 858 | 909 |
| 1320 | 1221 | 1142 | 1023 | 1074 | 1365 | 1516 | 1447 | 1058 | 1119 |
| 1350 | 1231 | 1242 | 1233 | 1084 | 1375 | 1556 | 1487 | 1228 | 1159 |
| 1410 | 1331 | 1282 | 1273 | 1174 | 1745 | 1616 | 1587 | 1238 | 1249 |
| 1430 | 1351 | 1362 | 1443 | 1274 | 1755 | 1786 | 1637 | 1248 | 1309 |
| 1490 | 1391 | 1392 | 1663 | 1304 | 1845 | 2056 | 1717 | 1348 | 1329 |
| 1580 | 1401 | 1642 | 1753 | 1314 | 1905 | | 1817 | 1398 | 1349 |
| 1660 | 1421 | 1812 | 1813 | 1384 | 1915 | | 1827 | 1478 | 1399 |
| 1810 | 1501 | 1852 | 1863 | 1394 | 1955 | | 1847 | 1528 | 1439 |
| 1830 | 1541 | 1912 | 1873 | 1454 | | | 2107 | 1638 | 1449 |
| 1990 | 1681 | 1992 | 1973 | 1674 | | | 2137 | 1678 | 1619 |
| 2210 | 1691 | 2022 | | 1754 | | | | 1838 | 1799 |
| | 1731 | 2102 | | 1814 | | | | 1898 | 1809 |
| | 1781 | | | 1824 | | | | 1918 | 1869 |
| | 1811 | | | 2144 | | | | 2098 | 2119 |
| | 1831 | | | | | | | 2208 | 2189 |
| | 1841 | | | | | | | | |
| | 1851 | | | | | | | | |
| | 1931 | | | | | | | | |
| | 1961 | | | | | | | | |
| | 1991 | | | | | | | | |
| | 2071 | | | | | | | | |
| | 2101 | | | | | | | | |
| | 2181 | | | | | | | | |
| | 2201 | | | | | | | | |

# Nitroglycerin (Liquid)

**Composition:**

| | % |
|---|---|
| C | 15.9 |
| H | 2.2 |
| N | 18.5 |
| O | 63.4 |
| C/H Ratio | 0.109 |



**Molecular Weight:** $(C_3H_5N_3O_9)$ 227

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | 3.5 |
| CO % | 24.5 |

**Density:** gm/cc

| | |
|---|---|
| 25°C, Liquid | 1.591 |
| 20°C, Liquid | 1.596 |

**Melting Point:** °C

| | |
|---|---|
| Labile form | 2.2 |
| Stable form | 13.2 |

**Freezing Point:** °C

**Boiling Point:** °C

| | |
|---|---|
| Decomposes | 145 |

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 15 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. 1 lb wt | 1 |
| Sample Wt, mg | |

**Refractive Index,**

| | |
|---|---|
| $n_{20}^{D}$ | 1.4732 |
| $n_{25}^{D}$ | 1.4713 |
| $n_{30}^{D}$ | |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Explodes |
| Fiber Shoe | |

**Vacuum Stability Test:**

cc/40 Hrs, at

| | |
|---|---|
| 90°C cc/gm/6 hrs | 1.6 |
| 100°C cc/gm/16 hrs | 11+ |
| 120°C | |
| 135°C | |
| 150°C | |

**Rifle Bullet Impact Test:**

| | Trials % |
|---|---|
| Explosions | 100 |
| Partials | 0 |
| Burned | 0 |
| Unaffected | 0 |

**200 Gram Bomb Sand Test:**

| | |
|---|---|
| Sand, gm Liquid method | 51.5 |

**Explosion Temperature:** °C

Seconds, 0.1 (no cap used)

| | | |
|---|---|---|
| 1 | | |
| 5 | Explodes | 222 |
| 10 | | |
| 15 | | |
| 20 | | |

**Sensitivity to Initiation:**

Minimum Detonating Charge, gm

- Mercury Fulminate
- Lead Azide
- Tetryl

**Ballistic Mortar, % TNT:** (a) 140

**Trauzl Test, % TNT:** (b) 181

**75°C International Heat Test:**

% Loss in 48 Hrs

**Plate Dent Test:**

- Method
- Condition
- Confined
- Density, gm/cc
- Brisance, % TNT

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 3.6 |
| % Loss, 2nd 48 Hrs | 3.5 |
| Explosion in 100 Hrs | None |

**Detonation Rate:**

| Confinement | Glass | Steel |
|---|---|---|
| Condition | Liquid | Liquid |
| Charge Diameter, in. | 0.39 | 1.25 |
| Density, gm/cc | 1.6 | 1.6 |
| Rate, meters/second | 1600-1900 | 7700 |

**Flammability Index:**

**Hygroscopicity:** % 30°C, 90% RH 0.06

**Volatility:** 60°C, $mg/cm^2/hr$ 0.11

# Nitroglycerin (Liquid)

**Booster Sensitivity Test:**
- Condition
- Tetryl, gm
- Wax, in. for 50% Detonation
- Wax, gm
- Density, gm/cc

**Heat of:**

| | |
|---|---|
| Combustion, cal/gm | 1616 |
| Explosion, cal/gm | 1600 |
| Gas Volume, cc/gm | 715 |
| Formation, cal/gm | 400 |
| Fusion, cal/gm | |
| Detonation, cal/gm | 1486 |

**Specific Heat:** cal/gm/°C

| | |
|---|---|
| Liquid | 0.356 |
| Solid | 0.315 |

**Burning Rate:**
cm/sec

**Thermal Conductivity:**
cal/sec/cm/°C

**Coefficient of Expansion:**
- Linear, %/°C
- Volume, %/°C

**Hardness, Mohs' Scale:**

**Young's Modulus:**
- E', dynes/cm²
- E, lb/inch²
- Density, gm/cc

**Compressive Strength:** lb/inch²

**Vapor Pressure:**

| °C | mm Mercury | °C | mm Mercury |
|---|---|---|---|
| 20 | 0.00025 | 60 | 0.0188 |
| 30 | 0.00083 | 70 | 0.043 |
| 40 | 0.0024 | 80 | 0.098 |
| 50 | 0.0073 | 90 | 0.23 |

**Decomposition Equation:**

| | | |
|---|---|---|
| Oxygen, atoms/sec (Z/sec) | $10^{17.3}$ | $10^{19.2}$ |
| Heat, kilocalorie/mole (ΔH, kcal/mol) | 41.4 | 45.0 |
| Temperature Range, °C | 90-135 | 125-150 |
| Phase | Liquid | Liquid |

**Armor Plate Impact Test:**

**60 mm Mortar Projectile:**
- 50% Inert, Velocity, ft/sec
- Aluminum Fineness

**500-lb General Purpose Bombs:**

Plate Thickness, inches
- 1
- 1¼
- 1½
- 1¾

**Bomb Drop Test:**

**T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:**

Max Safe Drop, ft

**500-lb General Purpose Bomb vs Concrete:**
- Height, ft
- Trials
- Unaffected
- Low Order
- High Order

**1000-lb General Purpose Bomb vs Concrete:**
- Height, ft
- Trials
- Unaffected
- Low Order
- High Order

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**Fragment Velocity:** ft/sec

At 9 ft

At 25½ ft

Density, gm/cc

**Blast (Relative to TNT):**

**Air:**

Peak Pressure

Impulse

Energy

**Air, Confined:**

Impulse

**Under Water:**

Peak Pressure

Impulse

Energy

**Underground:**

Peak Pressure

Impulse

Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Colorless

**Principal Uses:** Propellant ingredient, demolition explosive ingredient, grenade burster ingredient

**Method of Loading:**

**Loading Density:** gm/cc

**Storage:**

Method: With acetone or other desensitizer, generally not stored

Hazard Class (Quantity-Distance): Class 9

Compatibility Group

Exudation

Heat of Transition, cal/gm:

Transition:

| | |
|---|---|
| Liquid ⟶ labile | 5.2 |
| Labile ⟶ stable | 28.0 |
| Liquid ⟶ stable | 33.2 |

Hydrolysis, % Acid:

| | |
|---|---|
| 10 days at 22°C | < 0.002 |
| 5 days at 60°C | 0.005 |

82.1°C KI Test:

Minutes: 10+

## Nitroglycerin (Liquid)

Gas Evolved at Atmospheric Pressure, cc:

| Sample Wt, gm | 1.6 | |
|---|---|---|
| Temperature, °C | 65 | 75 |
| Time, hours | 20 | 40 |
| Volume of gas, cc | nil | nil |

Viscosity: (c)

| °C | Centipoises |
|---|---|
| 10 | 69.2 |
| 20 | 36.0 |
| 30 | 21.0 |
| 40 | 13.6 |
| 50 | 9.4 |
| 60 | 6.8 |

Fragmentation Test:

20 mm HE, Mark 1, Projectile, Total No. of Fragments for:

| | |
|---|---|
| Nitroglycerin | 22 |
| Tetranitromethane | 17 |

Minimum Propagating Diameter: (d)

| % Dimethylphthalate in NG | Min. Propagating Diameter, inches | Maximum Diameter for 2 Failures in 2 Trials, inches |
|---|---|---|
| 0 | (3/16 Cairns) | 1/16 |
| 5 | -- | 1/8 |
| 10 | 1/8 | 3/16 |
| 15 | 1/4 | 3/8 |
| 20 | 3/4 | 7/8 |
| 22.5 | 1 | 1-1/2 |
| 25 | 1.55 | 2 |

Sensitivity to Electrostatic Discharge, Joules (test condition, unconfined; no value given for confinement): > 12.5

Solubility, grams of nitroglycerin/100 gm (%) of:

| Water | | Alcohol | | Trichlorethylene | | Carbon Tetrachloride | |
|---|---|---|---|---|---|---|---|
| °C | % | °C | % | °C | % | °C | % |
| 15 | 0.16 | 0 | 37.5 | Rm | 22 | Rm | 2 |
| 20 | 0.18 | 20 | 54.0 | | | | |
| 50 | 0.25 | | | | | | |

| Carbon Disulfide | | gm/100 gm (%), at 25°C in | |
|---|---|---|---|
| °C | % | Ether | ∞ |
| | | 2:1, Ether:Alcohol | > 100 |
| Ambient | 1 | Acetone | ∞ |

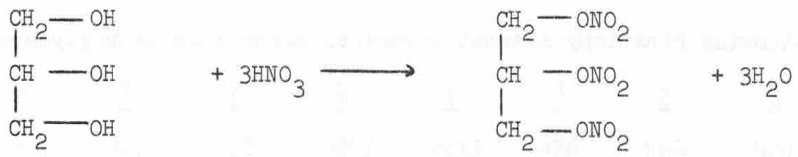
Soluble in all Proportions in:

| | |
|---|---|
| Methanol | Phenol |
| Acetone | Pyridine |
| Ether | Xylene |
| Ethyl acetate | Nitrobenzene |
| Amyl acetate | p-Nitrotoluene |
| Methyl nitrate | Liquid DNT |
| Ethyl nitrate | Chloroform |
| Nitroglycol | Ethyl chloride |
| Tetranitrodiglycerine | Ethyl bromide |
| Acetic acid | Tetrachloroethylene |
| Benzene | Dichloroethylene |
| Toluene | Trimethyleneglycol Dinitrate |

Solubility in NG, of:

| Alcohol | | DNT | | TNT | | Water | |
|---|---|---|---|---|---|---|---|
| °C | % | °C | % | °C | % | °C | % |
| 0 | 3.4 | 20 | 35 | 20 | 30 | 25 | 0.06 |
| 20 | 5.4 | | | | | | |
| 50 | ∞ | | | | | | |

Preparation:



Glycerine is usually nitrated at 25°C, or below, by adding it very slowly to a well agitated mixture of nitric and sulfuric acids, e.g., 40/59.5/0.5, nitric acid/sulfuric acid/water, using an acid/glycerine ratio of approximately 6. Agitation of the reaction mixture is accomplished by use of compressed air. A rapid temperature rise, or appearance of red fumes, automatically requires dumping of the charge, immediately, into a drowning vessel filled with water. After all the glycerine has been added to the nitrator, agitation and cooling are continued until the temperature drops to about 15°C, and the charge is then run into a separator where the NG rises to the top, and is run off to the neutralizer. The nitroglycerin is washed first with water, then with sodium carbonate, and finally with water. The resultant NG when washed with water, produces washings which do not color phenolphthalein, and itself is neutral to litmus paper.

# Nitroglycerin (Liquid)

Origin:

Nitroglycerin was first prepared in 1846 or 1847 by Ascanio Sobrero, an Italian chemist (Mem Acad Torino (2) 10, 195 (1847)). For several years after this discovery, nitroglycerin attracted little interest as an explosive until Alfred Nobel in 1864 patented improvements in its manufacture and method of initiation (British Patent 1813). Nobel gave the name dynamite to mixtures of nitroglycerin and non-explosive absorbents, such as charcoal, siliceous earth or Kieselguhr (British Patent 1345 (1867)). Later developments led to gelatine dynamites, ammonia dynamites, and so called straight dynamites. The first propellants using nitroglycerin were called Ballistite (Nobel, British Patent 1471 (1888)) and Cordite (Abel and Dewar, British Patents 5614 and 11,664 (1889)).

Destruction by Chemical Decomposition:

Nitroglycerin is decomposed by adding it slowly to 10 times its weight of 18% sodium sulfide ($Na_2S \cdot 9H_2O$). Heat is liberated by this reaction; but this is not hazardous if stirring is maintained during the addition of nitroglycerin and continued until solution is complete.

References: [48]

(a) A. H. Blatt, Compilation of Data on Organic Explosives, OSRD Report No. 2014, 29 February 1944.

(b) Ph. Naoum, Z ges Schiess-Sprengstoffw, pp. 181, 229, 267 (27 June 1932).

(c) Landolt - Bornstein, Physikalisch-Chemische Tabellen, 5th Ed. (1923).

International Critical Tables.

B. T. Fedoroff et al, A Manual for Explosive Laboratories, Vol I-IV, Lefax Society, Inc., Philadelphia, 1943, 1946.

(d) H. A. Strecker, Initiation, Propagation and Luminosity Studies of Liquid Explosives, OSRD Report No. 5609, 3 December 1945.

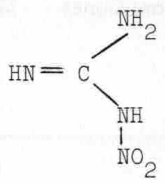
(e) Also see the following Picatinny Arsenal Technical Reports on Nitroglycerin:

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 620 | 511 | 652 | 233 | 454 | 1155 | 1206 | 817 | 768 | 69 |
| 660 | 551 | 672 | 343 | 494 | 1235 | 1456 | 837 | 1348 | 249 |
| 800 | 701 | 792 | 673 | 1024 | 1955 | 1496 | 1197 | 1398 | 579 |
| 1020 | 891 | 922 | 903 | 1074 | 2015 | 1556 | 1297 | 1738 | 709 |
| 1150 | 911 | 1142 | 1023 | 1084 | | 1616 | 1637 | 1918 | 1349 |
| 1210 | 1031 | 1282 | 1443 | 1454 | | 1786 | 1817 | 2098 | 1359 |
| 1410 | 1041 | 1362 | 1643 | 1524 | | 1816 | 1847 | | 2119 |
| 1620 | 1151 | 1542 | 1663 | 1624 | | 1896 | | | |
| 1680 | 1191 | 1662 | 1863 | 1674 | | 2056 | | | |
| | 1221 | 1692 | 1993 | 1754 | | | | | |
| | 1611 | 1742 | | | | | | | |
| | 1651 | 1752 | | | | | | | |
| | 1691 | 1992 | | | | | | | |
| | 1731 | | | | | | | | |
| | 1781 | | | | | | | | |
| | 1851 | | | | | | | | |
| | 1931 | | | | | | | | |
| | 2021 | | | | | | | | |
| | 2181 | | | | | | | | |
| | 2201 | | | | | | | | |

[48] See footnote 1, page 10.

**Composition:**

| | % |
|---|---|
| C | 11.5 |
| H | 3.9 |
| N | 53.8 |
| O | 30.8 |



C/H Ratio 0.038

**Molecular Weight:** ($CH_4N_4O_2$) 104

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -31 |
| CO % | -15.4 |

**Density:** gm/cc Crystal 1.72

**Melting Point:** °C 232

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 47 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 26 |
| Sample Wt, mg | 7 |

**Friction Pendulum Test:** (e)

| | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | Unaffected |

**Vacuum Stability Test:**

| cc/40 Hrs, at | |
|---|---|
| 90°C | |
| 100°C | 0.37 |
| 120°C | 0.44 |
| 135°C | |
| 150°C | |

**Rifle Bullet Impact Test:** 5 Trials (e)

| | % |
|---|---|
| Explosions | 0 |
| Partials | 0 |
| Burned | 0 |
| Unaffected | 100 |

**200 Gram Bomb Sand Test:**

Sand, gm 36.0

**Explosion Temperature:** °C

Seconds, 0.1 (no cap used)

| | | |
|---|---|---|
| 1 | | |
| 5 | Decomposes | 275 |
| 10 | | |
| 15 | | |
| 20 | | |

**Sensitivity to Initiation:**

Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | |
| Lead Azide | 0.20 |
| Tetryl | 0.10 |

**Ballistic Mortar, % TNT:** (a) 104

**Trauzl Test, % TNT:** (b) 101

**75°C International Heat Test:**

% Loss in 48 Hrs 0.04

**Plate Dent Test:** (c)

| | |
|---|---|
| Method | A |
| Condition | Pressed |
| Confined | No |
| Density, gm/cc | 1.50 |
| Brisance, % TNT | 95 |

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.18 |
| % Loss, 2nd 48 Hrs | 0.09 |
| Explosion in 100 Hrs | None |

**Detonation Rate:** (e)

| | |
|---|---|
| Confinement | |
| Condition | |
| Charge Diameter, in. | |
| Density, gm/cc | 1.55 |
| Rate, meters/second | 7650 |

**Flammability Index:**

**Hygroscopicity:** % 30°C, 90% RH None

**Volatility:** None

Nitroguanidine

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**Fragment Velocity:** ft/sec

At 9 ft

At 25½ ft

Density, gm/cc

**Blast (Relative to TNT):**

**Air:**

Peak Pressure

Impulse

Energy

**Air, Confined:**

Impulse

**Under Water:**

Peak Pressure

Impulse

Energy

**Underground:**

Peak Pressure

Impulse

Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Colorless

**Principal Uses:**

Propellant composition ingredient, bursting charge ingredient

**Method of Loading:**

**Loading Density:** gm/cc

At 3000 psi 0.95

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | |

Solubility, gm/100 gm (%), in:

| | °C | % |
|---|---|---|
| Water | 25 | 0.44 |
| | 100 | 9.0 |
| 1.0 N Potassium Hydroxide | 25 | 1.2 |
| 40% Sulfuric Acid | 0 | 3.4* |
| | 25 | 8.0* |

* gm/100 cc solution

Booster Sensitivity Test: (d)

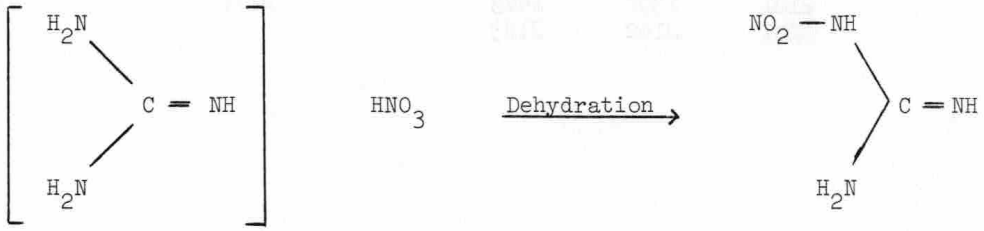
| | |
|---|---|
| Condition | Pressed |
| Tetryl, gm | 100 |
| Wax, in. for 50% Detonation | 0.67 |
| Density, gm/cc | 1.41 |

Heat of:

| | |
|---|---|
| Combustion, cal/gm | 1995 |
| Explosion, cal/gm | 721 |
| Gas Volume, cc/gm | 1077 |
| Formation, cal/gm | 227 |

Preparation:

(Chemistry of Powder and Explosives, Davis)




Four hundred gms of dry guanidine nitrate is added in small portions to 500 cc concentrated sulfuric acid at 10°C, or below. As soon as all crystals have disappeared the milky solution is poured into 3 liters of ice-water, and allowed to stand until crystallization is complete. The product is filtered, rinsed with water, and recrystallized from about 4 liters of boiling water, yield about 90%.

Origin:

Nitroguanidine was first prepared in 1877 by Jousselin, but it was 1900 before it found use in propellant compositions. During World War I, nitroguanidine was used by the Germans as an ingredient of bursting charge explosives.

Destruction by Chemical Decomposition:

Nitroguanidine is decomposed by dissolving in 15 times its weight of 45% sulfuric acid at room temperature and warming the solution until gas is evolved. Heating is continued for one-half hour.

References:[49]

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) Canadian Report, CE-12, 1 May-15 August 1941.

(c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(d) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

(e) Departments of the Army and the Air Force TM 9-1910/TO 11A-1-34, Military Explosives, April 1955.

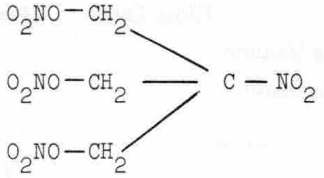
[49]See footnote 1, page 10.

(f) Also see the following Picatinny Arsenal Technical Reports on Nitroguanidine:

| 0 | 1 | 2 | 3 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|
| 1490 | 1391 | 1282 | 1183 | 1336 | 907 | 758 | 1439 |
| | 2181 | 1392 | 1423 | | 2177 | | 1749 |
| | 2201 | 2142 | 2193 | | | | |

**Composition:**

| | % |
|---|---|
| C | 16.8 |
| H | 2.1 |
| N | 19.6 |
| O | 61.5 |



C/H Ratio 0.126

**Molecular Weight:** ($C_4H_6N_4O_{11}$) 286

**Oxygen Balance:**
$CO_2$ % 0.0
CO % 22

**Density:** gm/cc 20°C 1.64

**Melting Point:** °C

**Freezing Point:** °C -39

**Boiling Point:** °C

**Refractive Index,** $n_{20}^D$

$n_{25}^D$ 1.4896

$n_{30}^D$ 1.4874

**Impact Sensitivity, 2 Kg Wt:**
Bureau of Mines Apparatus, cm 25
Sample Wt 20 mg
Picatinny Arsenal Apparatus, in.
Sample Wt, mg

**Friction Pendulum Test:**
Steel Shoe
Fiber Shoe

**Vacuum Stability Test:**
cc/40 Hrs, at
90°C
100°C
120°C
135°C
150°C

**Rifle Bullet Impact Test:** Trials

| | % |
|---|---|
| Explosions | |
| Partials | |
| Burned | |
| Unaffected | |

**200 Gram Bomb Sand Test:**
Sand, gm 0.2 gm sample absorbed by 0.2 gm of kieselguhr 28

**Explosion Temperature:** °C
Seconds, 0.1 (no cap used)

| | | |
|---|---|---|
| 1 | | |
| 5 | Ignites | 185 |
| 10 | | |
| 15 | | |
| 20 | | |

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm
Mercury Fulminate
Lead Azide
Tetryl

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**75°C International Heat Test:**
% Loss in 48 Hrs

**Plate Dent Test:**
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**100°C Heat Test:**
% Loss, 1st 48 Hrs
% Loss, 2nd 48 Hrs
Explosion in 100 Hrs

**Detonation Rate:**

| | |
|---|---|
| Confinement | Glass (1 mm wall) |
| Condition | Liquid |
| Charge Diameter, in. | 0.39 |
| Density, gm/cc | 1.64 |
| Rate, meters/second | 7860 |

**Flammability Index:**

**Hygroscopicity:** %

**Volatility:**
25°C, mg/cm²/24 hrs $0.127 \times 10^{-3}$

# Nitroisobutylglycerol Trinitrate (NIBTN) Liquid

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**Fragment Velocity:** ft/sec

At 9 ft

At 25½ ft

Density, gm/cc

**Blast (Relative to TNT):**

**Air:**

Peak Pressure

Impulse

Energy

**Air, Confined:**

Impulse

**Under Water:**

Peak Pressure

Impulse

Energy

**Underground:**

Peak Pressure

Impulse

Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Yellow oil

**Principal Uses:** Gelatinizing agent for nitrocellulose

**Method of Loading:**

**Loading Density:** gm/cc

**Storage:**

Method: Liquid

Hazard Class (Quantity-Distance)

Compatibility Group

Exudation

Solubility:

Soluble in methyl and ethyl alcohols, acetone, ether, ethylenedichloride, chloroform and benzene.

Insoluble in water, carbon disulphide, and petroleum ether.

Toxicity:

Slight, decidedly less than nitroglycerin.

Gelatinizing Action:

Slight on nitrocellulose.

82.2°C KI Test:

Minutes: 2

Preparation:

A total of 675 gm 37% formalin is added to 150 gm nitromethane containing 2 gm potassium carbonate hemi-hydrate. The first 200 gm formalin is added slowly, keeping the temperature below 30°C, and then the heat of reaction is allowed to raise the temperature to 80°C, and the mixture then heated two hours at 90°C. The reaction mixture is then concentrated at reduced pressure and diluted, and this process repeated several times to remove formaldehyde. After the final concentration the cooled mixture is filtered and the crystalline product recrystallized from alcohol and then several times from ether and dried.

The nitrated product is then obtained by nitrating 50 gm nitroisobutylglycerol with 300 gm mixed acid (60/38/2, sulfuric acid/nitric acid/water) below 15°C for 1.5 hours.

Origin:

This explosive (also called Trimethylolnitromethane Trinitrate, Nitroisobutanetriol Trinitrate, Nitroisobutylglycerin Trinitrate and incorrectly but widely used Nitroisobutylglycerol Trinitrate) was first described in 1912 by Hofwimmer (Z ges Schiess - Sprengstoffw 7, 43 (1912). Hofwimmer prepared the compound by the condensation of 3 moles of formaldehyde with 1 mole of nitromethane in the presence of potassium bicarbonate, the subsequent nitration of the product. The explosive can now be produced from coke, air, and natural gas.

References:[50]

(a) H. A. Aaronson, Study of Explosives Derived from Nitroparaffins, PATR No. 1125, 24 October 1941.

(b) M. Aubry, Mém poudr, 25, 197-204 (1932-33); CA 27, 4083 (1933).

(c) A. Stettbacher, Nitrocellulose 5, 159-62, 181-4, 203-6 (1934); CA 29, 1250 (1935).

(d) W. de C. Crater, U.S. Patent 2,112,749 (March 1938); CA 32, 3964 (1938).

(e) H. J. Hibshman, E. H. Pierson, and H. B. Haas, Ind Eng Chem 32, 427-9 (1940); CA 34, 3235 (1940).

(f) A. Stettbacher, Z ges Schiess Sprengstoffw 37, 62-4 (1942); CA 38, 255 (1944).

[50]See footnote 1, page 10.

# Nitrostarch Demolition Explosive (NSX)

**Composition:**

| | % |
|---|---|
| Nitrostarch (12.50% N) | 49 |
| Barium Nitrate | 40 |
| Mononitronaphthalene | 7 |
| Paranitroaniline | 3 |
| Oil | 1 |
| C/H Ratio | |

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 21 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 8 |
| Sample Wt, mg | |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Crackles, snaps |
| Fiber Shoe | Unaffected |

**Rifle Bullet Impact Test:**

| | 10 Trials % | 8 Trials* % |
|---|---|---|
| Explosions | 90 | 0 |
| Partials | 0 | 13 |
| Burned | 0 | 0 |
| Unaffected | 10 | 87 |

*Packed in paper

**Explosion Temperature:**

| Seconds | °C |
|---|---|
| 0.1 (no cap used) | -- |
| 1 | -- |
| 5 Decomposes | 195 |
| 10 | |
| 15 | |
| 20 | |

**75°C International Heat Test:**

| | |
|---|---|
| % Loss in 48 Hrs | 0.2 |

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.3 |
| % Loss, 2nd 48 Hrs | 0.3 |
| Explosion in 100 Hrs | None |

**Flammability Index:**

**Hygroscopicity:** % 30°C, 90% RH 2.1

**Volatility:**

**Molecular Weight:** 325

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -19 |
| CO % | 8 |

**Density:** gm/cc

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Vacuum Stability Test:**

| cc/40 Hrs, at | |
|---|---|
| 90°C | |
| 100°C | 11+ |
| 120°C | |
| 135°C | |
| 150°C | |

**200 Gram Bomb Sand Test:**

| | |
|---|---|
| Sand, gm | 39.5 |

**Sensitivity to Initiation:**

| Minimum Detonating Charge, gm | |
|---|---|
| Mercury Fulminate | 0.26 |
| Lead Azide | -- |
| Tetryl | -- |

**Ballistic Mortar, % TNT:** (a) 96

**Trauzl Test, % TNT:**

**Plate Dent Test:**

Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**Detonation Rate:**

Confinement
Condition
Charge Diameter, in.
Density, gm/cc
Rate, meters/second

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**Fragment Velocity:** ft/sec

At 9 ft

At 25½ ft

Density, gm/cc

**Blast (Relative to TNT):**

**Air:**

Peak Pressure

Impulse

Energy

**Air, Confined:**

Impulse

**Under Water:**

Peak Pressure

Impulse

Energy

**Underground:**

Peak Pressure

Impulse

Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:**

**Principal Uses:** Demolition, bursting charges, and priming compositions

**Method of Loading:** Hand tamped

**Loading Density:** gm/cc

Apparent 0.92

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | None |

120°C Heat Test:

| | Minutes |
|---|---|
| Salmon Pink | 70 |
| Red Fumes | 255 |
| Explodes | 256 |

## Nitrostarch Demolition Explosive (NSX)

Preparation: (b)

The nitration of starch proceeds with the formation of hexanitro starch according to the following equation:

$$2C_6H_{10}O_5 + 6HNO_3 \rightarrow C_{12}H_{14}O_4(ONO_2)_6 + 6H_2O$$

Tapioca starch is considered the best for nitration purposes, although other starches give fairly stable products. The starch, pretreated to remove oils, fats and water soluble impurities, is dried and screened. Feeding of the dried starch into stainless steel nitrators containing mixed acid (62%-63% $HNO_3$ and 37%-38% $H_2SO_4$) is done slowly with constant agitation of the mixture. The heat evolved must be controlled by cooling coils. The nitrated starch is separated from the spent acid, washed with a large amount of water and centrifuged. Final drying is on trays heated to 35°-40°C with air. This product is so sensitive even a static discharge might cause explosion.

Nitrostarch demolition explosives contain a high percentage of nitrostarch, an oxidizing agent, mineral oil, a stabilizer and/or other ingredients.

Origin:

Nitrostarch was first prepared in 1833 by Branconnot, who called it xyloidine (Ann chim phys [2] 52, 290 (1833)). T. J. Pelouze studied xyloidine further and reported its explosive properties (Compt rend 7, 713 (1838). It found military use in the United States during World Wars I and II as blasting explosives and as an ingredient of bursting charges and priming compositions.

References:[51]

(a) W. R. Tomlinson, Jr., Physical and Explosive Properties of Military Explosives, PATR No. 1372, 29 November 1943.

(b) G. D. Clift and B. T. Fedoroff, A Manual for Explosives Laboratories, Vol I, Lefax Society, Inc., Philadelphia (1942).

(c) Also see the following Picatinny Arsenal Technical Reports on Nitrostarch Explosives:

| 1 | 2 | 4 | 7 | 8 | 9 |
|---|---|---|---|---|---|
| 1611 | 782<br>2032 | 1034 | 1117 | 838<br>848 | 1269 |

[51] See footnote 1, page 10.

# Octol, 70/30

**Composition:**

| | % |
|---|---|
| HMX | 70 |
| TNT | 30 |

C/H Ratio

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 18 |
| Sample Wt, mg | 26 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | Unaffected |

**Rifle Bullet Impact Test:** Trials

| | % |
|---|---|
| Explosions | |
| Partials | |
| Burned | |
| Unaffected | |

**Explosion Temperature:**

| | | °C |
|---|---|---|
| Seconds, 0.1 | (no cap used) | --- |
| 1 | | --- |
| 5 | Flames erratically | 335 |
| 10 | | |
| 15 | | |
| 20 | | |

**75°C International Heat Test:**
% Loss in 48 Hrs

**100°C Heat Test:**
% Loss, 1st 48 Hrs
% Loss, 2nd 48 Hrs
Explosion in 100 Hrs

**Flammability Index:**

**Hygroscopicity:** %

**Volatility:**

**Molecular Weight:** 265

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -38 |
| CO % | -7.5 |

**Density:** gm/cc Cast 1.80

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$
$n_{25}^{D}$
$n_{30}^{D}$

**Vacuum Stability Test:**
cc/40 Hrs, at

| | |
|---|---|
| 90°C | ---- |
| 100°C | ---- |
| 120°C | 0.37 |
| 135°C | |
| 150°C | |

**200 Gram Bomb Sand Test:**
Sand, gm Exploratory 58.4

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | ---- |
| Lead Azide | 0.30 |
| Tetryl | ---- |

**Ballistic Mortar, % TNT:** 115

**Trauzl Test, % TNT:**

**Plate Dent Test:**
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**Detonation Rate:**

| | |
|---|---|
| Confinement | None |
| Condition | Cast |
| Charge Diameter, in. | 1.0 |
| Density, gm/cc | 1.80 |
| Rate, meters/second | 8377 |

Octol, 70/30

**Booster Sensitivity Test:**
- Condition
- Tetryl, gm
- Wax, in. for 50% Detonation
- Wax, gm
- Density, gm/cc

**Heat of:**

| | |
|---|---|
| Combustion, cal/gm | 2722 |
| Explosion, cal/gm | 1074 |
| Gas Volume, cc/gm | 847 |
| Formation, cal/gm | ---- |
| Fusion, cal/gm | |

**Specific Heat:** cal/gm/°C

**Burning Rate:**
cm/sec

**Thermal Conductivity:**
cal/sec/cm/°C

**Coefficient of Expansion:**
- Linear, %/°C
- Volume, %/°C

**Hardness, Mohs' Scale:**

**Young's Modulus:**
- E', dynes/cm²
- E, lb/inch²
- Density, gm/cc

**Compressive Strength:** lb/inch² — 1510 See below

**Vapor Pressure:**

| °C | mm Mercury |
|---|---|

| Compressive Strength: lb/inch² | * |
|---|---|
| Average (10 tests) | 1510 |
| High | 1740 |
| Low | 1330 |

**Decomposition Equation:**
- Oxygen, atoms/sec (Z/sec)
- Heat, kilocalorie/mole (ΔH, kcal/mol)
- Temperature Range, °C
- Phase

**Armor Plate Impact Test:**

**60 mm Mortar Projectile:**
- 50% Inert, Velocity, ft/sec
- Aluminum Fineness

**500-lb General Purpose Bombs:**

Plate Thickness, inches

- 1
- 1¼
- 1½
- 1¾

**Bomb Drop Test:**

**T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:**

Max Safe Drop, ft

**500-lb General Purpose Bomb vs Concrete:**

- Height, ft
- Trials
- Unaffected
- Low Order
- High Order

**1000-lb General Purpose Bomb vs Concrete:**

- Height, ft
- Trials
- Unaffected
- Low Order
- High Order

| Ultimate Deformation: % | |
|---|---|
| Average (10 tests) | 2.26 |
| High | 2.58 |
| Low | 1.97 |

*Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Buff

**Principal Uses:** HE projectile and bomb filler

**Method of Loading:** Cast

**Loading Density:** gm/cc 1.80

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | |

Work to Produce Rupture: ft-lb/inch$^3$ *

| | |
|---|---|
| Average (10 tests) | 1.55 |
| High | 1.87 |
| Low | 1.10 |

Efflux Viscosity, Saybolt Seconds: 5.9

*Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.

Effect of Altitude, Charge Diameter and Degree of Confinement on Detonation Velocity*
(Reference b)

| Explosive | Simulated Altitude, Feet | One-Inch Column | | Two-Inch Column | |
|---|---|---|---|---|---|
| | | Confined m/s | Unconfined m/s | Confined m/s | Unconfined m/s |
| 70/30, RDX/TNT; density, gm/cc 1.62 | Ground | 7900 | 8100 | 7660 | 8030 |
| | 30,000 | 8020 | 8120 | 7900(4) | 7800 |
| | 60,000 | 8040 | 8140 | 8010 | 7950 |
| | 90,000 | 8060 | 7980 | 8010 | 7710 |
| Average | | 8005 | 8085 | 7895 | 7873 |
| 70/30, HMX/TNT; density, gm/cc 1.61 | Ground | 7960 | 7900(4) | 7870 | 7640(4) |
| | 30,000 | 8050 | 8060 | 7930 | 7710 |
| | 60,000 | 8020 | 7930 | 7890 | 7650 |
| | 90,000 | 7950 | 8000 | 7940 | 7650 |
| Average | | 7995 | 7973 | 7908 | 7663 |

*70/30 Octol confined charge in 1/4" steel tube, AISI 1015 seamless, 1" diameter 18" long, and 2" diameter 7" long. All means were determined from sets of five values unless otherwise indicated by ( ). A 26 gm tetry booster was used to initiate each charge.

Average Fragment Velocities at Various Altitudes* (g)

| Explosive | Charge Diameter, Inches | Simulated Altitude, Feet | | | |
|---|---|---|---|---|---|
| | | Ground m/s | 30,000 m/s | 60,000 m/s | 90,000 m/s |
| 70/30, RDX/TNT | 1 | 3415 | 3672 | 3666 | 3685 |
| | 2 | 4647 | 5192 | 5236 | 6011 |
| 70/30, HMX/TNT | 1 | 3366 | 3680 | 4014 | 3617 |
| | 2 | 4703 | 5464 | 6089 | 6111 |

*Outside diameter 2.54"; inside diameter 2.04"; length 7".

Tensile Strength:*

| | $lb/inch^2$ |
|---|---|
| Average (8 tests) | 169 |
| High | 204 |
| Low | 128 |

*Test specimen as per Picatinny Arsenal sketch XL-076B, at 21°C.

Modulus of Elasticity:*

| | $lb/inch^2$ |
|---|---|
| Average (10 tests) | 73,200 |
| High | 79,300 |
| Low | 63,000 |

*Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.

Setback Sensitivity Test: (a)

| | |
|---|---|
| Critical Pressure | 92,000 psi* |
| Density, gm/cc | 1.72 |

*Pressure below which no initiation is obtained and above which an increasing percentage of initiations can be expected as the setback pressure increases.

Pit Fragmentation Test:

105 mm M1 HE Projectile:

| Weight Group, grains | No. of Fragments |
|---|---|
| 1/2 - 2 | 1297 |
| 2 - 5 | 665 |
| 5 - 10 | 497 |
| 10 - 25 | 661 |
| 25 - 50 | 471 |
| 50 - 75 | 247 |
| 75 - 150 | 322 |
| 150 - 750 | 295 |
| 750 - 2500 | 12 |
| Total Number | 4467 |

Octol, 75/25

**Composition:**

| | % |
|---|---|
| HMX | 75 |
| TNT | 25 |
| C/H Ratio | |

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | -- |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 17 |
| Sample Wt, mg | 25 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | Unaffected |

**Rifle Bullet Impact Test:** 10Trials %

| | 3/16" Steel | 1/8" Al |
|---|---|---|
| Explosions | 70 | 70 |
| Partials | -- | -- |
| Burned | -- | -- |
| Unaffected | 30 | 30 |

**Explosion Temperature:**

| Seconds, | | °C |
|---|---|---|
| 0.1 | (no cap used) | --- |
| 1 | | --- |
| 5 | Flames erratically | 350 |
| 10 | | |
| 15 | | |
| 20 | | |

**75°C International Heat Test:**
% Loss in 48 Hrs

**100°C Heat Test:**
% Loss, 1st 48 Hrs
% Loss, 2nd 48 Hrs
Explosion in 100 Hrs

**Flammability Index:**

**Hygroscopicity:** %

**Volatility:**

**Molecular Weight:** 276

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -35 |
| CO % | -6.3 |

**Density:** gm/cc Cast 1.81

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Vacuum Stability Test:**
cc/40 Hrs, at

| | |
|---|---|
| 90°C | ---- |
| 100°C | ---- |
| 120°C | 0.39 |
| 135°C | |
| 150°C | |

**200 Gram Bomb Sand Test:**
Sand, gm Exploratory 62.1

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | ---- |
| Lead Azide | 0.30 |
| Tetryl | ---- |

**Ballistic Mortar, % TNT:** 116

**Trauzl Test, % TNT:**

**Plate Dent Test:**
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**Detonation Rate:**

| | |
|---|---|
| Confinement | None |
| Condition | Cast |
| Charge Diameter, in. | 1.0 |
| Density, gm/cc | 1.81 |
| Rate, meters/second | 8643 |

**Booster Sensitivity Test:**
Condition
Tetryl, gm
Wax, in. for 50% Detonation
Wax, gm
Density, gm/cc

**Heat of:**

| | |
|---|---|
| Combustion, cal/gm | 2676 |
| Explosion, cal/gm | 1131 |
| Gas Volume, cc/gm | 830 |
| Formation, cal/gm | |
| Fusion, cal/gm | 29.4* |

*Calculated for 76.9% HMX, 23.1% TNT.

**Specific Heat:** cal/gm/°C **

| | |
|---|---|
| -79°C | 0.200 |
| -80° to +80°C | 0.240 |
| 33° to 74°C | 0.245 |
| 90° to 150°C | 0.323 |

**Determined for 76.9% HMX, 23.1% TNT.

**Burning Rate:**
cm/sec

**Thermal Conductivity:**
cal/sec/cm/°C

**Coefficient of Expansion:**
Linear, %/°C

Volume, %/°C

**Hardness, Mohs' Scale:**

**Young's Modulus:**
E', dynes/cm²
E, lb/inch²
Density, gm/cc

**Compressive Strength:** lb/inch² 1340
See below

**Vapor Pressure:**
°C mm Mercury

Compressive Strength: lb/inch² ***

| | |
|---|---|
| Average (10 tests) | 1340 |
| High | 1560 |
| Low | 1040 |

***Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.

**Decomposition Equation:**
Oxygen, atoms/sec (Z/sec)
Heat, kilocalorie/mole (ΔH, kcal/mol)
Temperature Range, °C
Phase

**Armor Plate Impact Test:**

**60 mm Mortar Projectile:**
50% Inert, Velocity, ft/sec
Aluminum Fineness

**500-lb General Purpose Bombs:**

Plate Thickness, inches

1
1¼
1½
1¾

**Bomb Drop Test:**

**T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:**

Max Safe Drop, ft

**500-lb General Purpose Bomb vs Concrete:**

Height, ft
Trials
Unaffected
Low Order
High Order

**1000-lb General Purpose Bomb vs Concrete:**

Height, ft
Trials
Unaffected
Low Order
High Order

Ultimate Deformation: %

| | |
|---|---|
| Average (10 tests) | 2.43 |
| High | 2.89 |
| Low | 2.04 |

Octol, 75/25

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Buff

**Principal Uses:** HE projectile and bomb filler

**Method of Loading:** Cast

**Loading Density:** gm/cc 1.81

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | |

Work to Produce Rupture: ft-lb/inch$^3$ *

| | |
|---|---|
| Average (10 tests) | 1.31 |
| High | 1.57 |
| Low | 1.07 |

Efflux Viscosity, Saybolt Seconds: 9.0

*Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.

Fragment Velocity Test: (a)

M26 Hand Grenade:

| Explosive | Average Fragment Velocity, ft/sec over 1st 6 feet |
|---|---|
| Composition B | 4948 |
| 75/25 Cyclotol | 4908 |
| 75/25 Octol | 5124 |

Tensile Strength:*

| | lb/inch$^2$ |
|---|---|
| Average (10 tests) | 266 |
| High | 330 |
| Low | 226 |

*Test specimen as per Picatinny Arsenal sketch XL-076B, at 21°C.

Modulus of Elasticity:*

| | lb/inch$^2$ |
|---|---|
| Average (10 tests) | 62,100 |
| High | 75,900 |
| Low | 45,200 |

*Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.

Setback Sensitivity Test: (a)

| | |
|---|---|
| Critical Pressure | 76,000 psi* |
| Density, gm/cc | 1.80 |

*Pressure below which no initiation is obtained and above which an increasing percentage of initiations can be expected as the setback pressure increases.

Pit Fragmentation Test: (a)

105 mm M1 HE Projectile:

| Weight Group, grains | No. of Fragments |
|---|---|
| 1/2 - 2 | 1611 |
| 2 - 5 | 777 |
| 5 - 10 | 535 |
| 10 - 25 | 719 |
| 25 - 50 | 480 |
| 50 - 75 | 246 |
| 75 - 150 | 339 |
| 150 - 750 | 293 |
| 750 - 2500 | 8 |
| Total Number | 5008 |

Preparation:

Water-wet HMX is added slowly to molten TNT in a steam-jacketed kettle at a temperature of 100°C. The mixture is heated and stirred until all moisture is evaporated. The composition is cooled to a satisfactory pouring temperature and cast directly into ammunition components or prepared in the form of chips to be stored for later use.

References:[52]

(a) 1st Indorsement from Chief, Explosives Development Section, to Chief, Explosives Research Section, Picatinny Arsenal, dated 12 May 1958. Subject: "Properties of Octols and HTA-3."

(b) A. W. O'Brien, Jr., C. W. Plummer, R. P. Woodburn and V. Philipchuk, Detonation Velocity Determinations and Fragment Velocity Determinations of Varied Explosive Systems and Conditions, National Northern Corporation Final Summary Report NNC-F-13, February 1958 (Contract DAI-19-020-501-ORD-(P)-58).

[52]See footnote 1, page 10.

**Composition:**

| | % |
|---|---|
| RDX | 90 |
| Polystyrene (unmodified) | 8.5 |
| Dioctylphthalate | 1.5 |
| C/H Ratio | |

**Impact Sensitivity, 2 Kg Wt:**

| | Unpressed |
|---|---|
| Bureau of Mines Apparatus, cm | 28 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 15 |
| Sample Wt, mg | 20 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | Unaffected |

**Rifle Bullet Impact Test:** 10 Trials *

| | % |
|---|---|
| Explosions | 10 |
| Partials | 90 |
| Burned | 0 |
| Unaffected | 0 |

**Explosion Temperature:**

| | °C |
|---|---|
| Seconds, 0.1 (no cap used) | --- |
| 1 | --- |
| 5 Smokes | 275 |
| 10 | |
| 15 | |
| 20 | |

**75°C International Heat Test:**
% Loss in 48 Hrs

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.00 |
| % Loss, 2nd 48 Hrs | 0.00 |
| Explosion in 100 Hrs | None |

**Flammability Index:**

**Hygroscopicity:** %

* Test procedure described in PATR No. 2247, May 1956.

**Molecular Weight:** 245

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -62 |
| CO % | -18 |

**Density:** gm/cc

| | |
|---|---|
| Unpressed | 0.81 |
| Pellet pressed at 30,000 psi | 1.62 |

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n^D_{20}$ $n^D_{25}$ $n^D_{30}$

**Vacuum Stability Test:**
cc/40 Hrs, at

| | |
|---|---|
| 90°C | ---- |
| 100°C | ---- |
| 120°C | 0.41 |
| 135°C | |
| 150°C | |

**200 Gram Bomb Sand Test:**
Sand, gm

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm
Mercury Fulminate
Lead Azide
Tetryl

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**Plate Dent Test:**
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**Detonation Rate:**
Confinement
Condition
Charge Diameter, in.
Density, gm/cc
Rate, meters/second

**Booster Sensitivity Test:**
- Condition
- Tetryl, gm
- Wax, in. for 50% Detonation
- Wax, gm
- Density, gm/cc

**Heat of:**
- Combustion, cal/gm — 3027
- Explosion, cal/gm — 983
- Gas Volume, cc/gm
- Formation, cal/gm
- Fusion, cal/gm

**Specific Heat:** cal/gm/°C

**Burning Rate:**
cm/sec

**Thermal Conductivity:**
cal/sec/cm/°C

**Coefficient of Expansion:**
- Linear, %/°C
- Volume, %/°C

**Hardness, Mohs' Scale:**

**Young's Modulus:** — See below
- E', dynes/cm²
- E, lb/inch²
- Density, gm/cc

| **Compressive Strength:** lb/inch² | 2403 | 2149 |
|---|---|---|
| Percent | 8.9 | 13.1 |

**Vapor Pressure:**

| °C | mm Mercury |
|---|---|

| Young's Modulus: * (a) | Temperature | |
|---|---|---|
| | Ambient | 95°C |
| E, lb/inch² (avg of 5) | 39,953 | 34,831 |
| Density, gm/cc | 1.60 | 1.57 |

**Decomposition Equation:**
- Oxygen, atoms/sec (Z/sec)
- Heat, kilocalorie/mole (ΔH, kcal/mol)
- Temperature Range, °C
- Phase

**Armor Plate Impact Test:**

**60 mm Mortar Projectile:**
- 50% Inert, Velocity, ft/sec
- Aluminum Fineness

**500-lb General Purpose Bombs:**

Plate Thickness, inches

- 1
- 1¼
- 1½
- 1¾

**Bomb Drop Test:**

**T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:**

Max Safe Drop, ft

**500-lb General Purpose Bomb vs Concrete:**
- Height, ft
- Trials
- Unaffected
- Low Order
- High Order

**1000-lb General Purpose Bomb vs Concrete:**
- Height, ft
- Trials
- Unaffected
- Low Order
- High Order

*Pellets (Lot OAC-596-55) 0.750 inch diameter by 0.750 inch long, pressed at 30,000 psi with 30-second dwell.

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** White

**Principal Uses:** High mechanical strength explosive

**Method of Loading:** Pressed

**Loading Density:** gm/cc — Pressed, psi x $10^3$

| 0 | 10 | 20 | 30 |
|---|---|---|---|
| 1.10 | 1.49 | 1.59 | 1.62 |

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | None |

Rockwell Hardness, "R" Scale: (a)
1/2 inch diameter Penetrator, 60 Kg Load:

| Pellet No.* | Specific Gravity | Hardness |
|---|---|---|
| 1 | 1.624 | 84 |
| 2 | 1.623 | 90 |
| 3 | 1.611 | 84 |
| 4 | 1.600 | 80 |
| 5 | 1.590 | 75 |
| 6 | 1.571 | 73 |
| 7 | 1.548 | 62 |
| 8 | 1.524 | 49 |

*Pellets (Lot HOL-E-93) were 1-1/2 inches in diameter and 3/4 inch high.

Sensitivity of PB-RDX and 98/2 RDX/Stearic Acid Pellets* to Initiation by Type II Special Blasting Caps (a)

| Pellets | Gap (Distance From Base of Cap to Pellet), Inches 0.250 | 0.300 | 0.350 | 0.400 | 0.450 | 0.500 | 0.750 |
|---|---|---|---|---|---|---|---|
| PB-RDX with Pellet Density 1.55 gm/cc | | | | | | | |
| No. of Trials | 1 | 8 | 5 | 6 | 2 | 1 | 1 |
| Average Depth of Plate Indentation, inches ** | 0.082 | 0.090 | 0.087 | 0.080 | 0.080 | — | — |
| No. of Failures | 0 | 1 | 3 | 4 | 1 | 1 | 1 |
| PB-RDX with Pellet Density 1.60 gm/cc | | | | | | | |
| No. of Trials | 3 | 8 | 9 | 4 | 3 | 5 | 2 |
| Average Depth of Plate Indentation, inches ** | 0.090 | 0.089 | 0.087 | 0.084 | 0.087 | 0.075 | — |
| No. of Failures | 0 | 0 | 2 | 3 | 2 | 3 | 2 |
| 98/2 RDX/Stearic Acid With Pellet Density 1.63 gm/cc | | | | | | | |
| No. of Trials | 5 | 3 | 5 | 5 | 5 | 5 | 5 |
| Average Depth of Plate Indentation, inches ** | 0.109 | 0.096 | 0.095 | 0.092 | 0.097 | 0.087 | — |
| No. of Failures | 0 | 1 | 0 | 3 | 4 | 4 | 5 |

* Pellets 0.92 inch diameter, 0.375 inch height.

** Mild steel plate 5" x 5" x 1".

Performance of PB-RDX as Booster: (b, d)

Ten 2.75 inch HEAT M1 Rocket Heads were unaffected in performance by storage at 71°C for 28 days. Thus, PB-RDX was not desensitized by contact with TNT-bearing explosives. Tetryl, similarly used, becomes desensitized when stored in bursting charges at elevated temperatures.

In addition, 108 modified M307A1 57 mm projectiles were fired for performance against armor. Each round contained a PB-RDX booster pellet. There was no evidence in these firings that the projectiles were inadequately boostered.

PB-RDX

Preparation:

The purchase description sheet for polystyrene-bonded RDX (X-PA-PD-1088, 25 October 1956) requires that the PB-RDX shall be a mixture of RDX, coated and surrounded by a homogeneous mixture of polystyrene and dioctylphthalate. The specified percentage of RDX shall consist of a mixture of 75% Type B, Class A RDX and 25% Type B, Class E RDX. The granulation of the unpressed composition shall be as follows:

| Through U. S. Standard Sieve No. | Minimum % | Maximum % |
|---|---|---|
| 6 | 100 | -- |
| 12 | 60 | -- |
| 20 | -- | 2 |
| 35 | -- | 0 |

Two methods have been reported for the preparation of PB-RDX (Reference: Los Alamos Scientific Laboratory, Contract W-7405-Eng 36 with U.S. Atomic Energy Commission, Report No. LA-1448). The earlier method employed a Baker-Perkins type mixer to blend the components. This procedure gave a product with good pressing characteristics. However, the molding composition was nonuniform in granulation and tended to be dusty. The slurry method of PB-RDX preparation gave a product which was uniform, free-flowing and dustless. In addition, PB-RDX granulated by the slurry method exhibited satisfactory drying, handling and pressing characteristics.

The final procedure incorporating the better features found from the study of such variables as solvents, solvent/plastic ratios, lacquer addition and temperature, agitation, RDX particle size distribution, dispersants and rosin additive, was as follows (Reference c):

Forty-two and five-tenths grams (42.5 gm) of polystyrene and 8 cc dioctylphthalate were dissolved in 200 cc toluene in a lacquer dissolver. Steam was introduced into the jacket until the temperature reached 65°C. The lacquer was agitated constantly until it was ready to be added to the granulator. This lacquer contained a 1:4 ratio of plastic-plasticizer to toluene.

Four hundred and fifty grams (450 gm) of RDX and 4500 grams of $H_2O$ (ratio 1:10) were added to the granulator. The agitator was set for 400 rpm and the temperature was raised to 75°C by introducing steam into the jacket. The temperature differential between the lacquer solution and the RDX/water slurry was 5° to 10°C.

The lacquer solution was poured through the charging funnel into the granulator. As soon as the lacquer was added, a solution of gelatin in water was added, and the mixture was agitated until the lacquer was well dispersed in the RDX slurry (approximately 5 minutes). Granulation took place at this point. Steam was introduced again into the jacket to distill the solvent until the temperature reached 98°C. Cooling water was then run into the jacket to cool the batch to 40°C. The coated material from the granulator was collected on a Buchner funnel and dried in a tray at 70°C for 24 hours. Temperatures below 70°C did not furnish enough heat, but a temperature of 80°C produced stickiness and caking of PB-RDX.

Origin:

An explosive consisting of RDX coated with polystyrene plasticized with dioctyphthalate was initially developed in 1952 for the Atomic Energy Commission by Los Alamos Scientific Laboratory of the University of California (Contract W-7405-Eng 36 with U. S. Atomic Energy

Commission, Report No. LA-1448). The specific formulation of 90/8.5/1.5 RDX/polystyrene/dioctylphthalate was subsequently standardized by Los Alamos. This explosive, originally designated PBX, has been redesignated PB-RDX. The detailed requirements for the present polystyrene-bonded RDX(PB-RDX) are given in purchase description X-PA-PD-1088, 25 October 1956.

References:[53]

(a) B. J. Zlotucha, T. W. Stevens and C. E. Jacobson, Characteristics of Polystyrene-Bonded RDX(PB-RDX), PATR No. 2497, April 1958.

(b) A. J. Pascazio, The Suitability of a Bare PBX Booster Pellet in the 2.75 Inch M1 HEAT Rocket Head, PATR No. 2271, November 1955.

(c) J. L. Vermillion and R. C. Dubberly, Plastic-Bonded RDX, Its Preparation by the Slurry Method, Holston Defense Corporation, Control No. 20-T-16 Series A (PAC 1081), 5 March 1953.

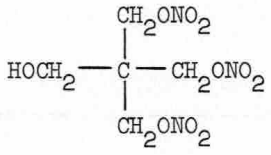
(d) C. J. Eichinger, Report on Cartridge HEAT 57 mm M307A1 (Mod) with Modified Copper Liner, Aberdeen Proving Ground, Development and Proof Services, First Report on OC Project TA3-5204, October 1957.

[53] See footnote 1, page 10.

**Composition:**

| | % |
|---|---|
| C | 22.1 |
| H | 3.3 |
| N | 15.5 |
| O | 59.1 |

C/H Ratio 0.141



**Molecular Weight:** ($C_5H_9N_3O_{10}$) 271

**Oxygen Balance:**
$CO_2$ % -27
CO % 3

**Density:** gm/cc 1.54

**Melting Point:** °C 26 to 28

**Freezing Point:** °C

**Boiling Point:** °C 4 mm Hg Decomposes 130

**Refractive Index,** $n_{20}^D$
$n_{25}^D$
$n_{30}^D$

**Impact Sensitivity, 2 Kg Wt:**
Bureau of Mines Apparatus, cm
Sample Wt 20 mg
Picatinny Arsenal Apparatus, in. 5 to 10
Sample Wt, mg 38

**Friction Pendulum Test:**
Steel Shoe
Fiber Shoe

**Vacuum Stability Test:**
cc/40 Hrs, at

| | |
|---|---|
| 90°C | ---- |
| 100°C | 2.54 to 5.69 |
| 120°C | |
| 135°C | |
| 150°C | |

**Rifle Bullet Impact Test:** Trials

| | % |
|---|---|
| Explosions | |
| Partials | |
| Burned | |
| Unaffected | |

**200 Gram Bomb Sand Test:**
Sand, gm

**Explosion Temperature:** °C
Seconds, 0.1 (no cap used)
1
5
10
15
20

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm
Mercury Fulminate
Lead Azide
Tetryl

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**75°C International Heat Test:**
% Loss in 48 Hrs

**Plate Dent Test:**
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**100°C Heat Test:**
% Loss, 1st 48 Hrs
% Loss, 2nd 48 Hrs
Explosion in 100 Hrs

**Detonation Rate:**
Confinement
Condition
Charge Diameter, in.
Density, gm/cc
Rate, meters/second

**Flammability Index:**

**Hygroscopicity:** %

**Volatility:**

# Pentaerythritol Trinitrate (PETRIN)

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

Absolute Viscosity, poises:

| | |
|---|---|
| Temp, 17°C | 14.8 |
| 23°C | 4.8 |
| 28°C | 3.0 |
| 38°C | 1.2 |

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** White

**Principal Uses:** Explosive, propellant or igniter ingredient

**Method of Loading:**

**Loading Density:** gm/cc

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | |
| Compatibility Group | |
| Exudation | None |

PETRIN esters are listed in reference (b) and most of these esters have been shown to have explosive properties.

An infrared spectrophotometric procedure was developed for the determination of the acetone content of PETRIN (ref c). A 2.5 gm sample of PETRIN is dissolved in chloroform and the volume increased to 25 milliliters in a volumetric flask. The acetone content of the PETRIN solution is determined by its infrared absorption at 5.82$\mu$ in a 0.5 mm cell. A double beam method is used with a reference cell containing chloroform and acetone-free PETRIN. The quantity of the latter must be carefully adjusted to give a good balance between the test sample and reference cells for the strong PETRIN peak at 6.02$\mu$ maximum.

Heat of:

| | |
|---|---|
| Explosion, cal/gm | 1204 |

**Booster Sensitivity Test:** (d) 50/50

| | | |
|---|---|---|
| Condition | Pressed | Cast |
| Tetryl, gm | 100 | 100 |
| Wax, in. for 50% Detonation | 2.36 | 2.08 |
| Wax, gm | | |
| Density, gm/cc | 1.60 | 1.65 |

**Heat of:**
- Combustion, cal/gm
- Explosion, cal/gm 1220
- Gas Volume, cc/gm
- Formation, cal/gm
- Fusion, cal/gm

**Specific Heat:** cal/gm/°C

**Burning Rate:**
cm/sec

**Thermal Conductivity:**
cal/sec/cm/°C

**Coefficient of Expansion:**
- Linear, %/°C
- Volume, %/°C

**Hardness, Mohs' Scale:**

**Young's Modulus:**
- E', dynes/cm²
- E, lb/inch²
- Density, gm/cc

**Compressive Strength:** lb/inch² 2000-2200
Density, gm/cc 1.68

**Vapor Pressure:**
°C mm Mercury

**Decomposition Equation:**
- Oxygen, atoms/sec (Z/sec)
- Heat, kilocalorie/mole (ΔH, kcal/mol)
- Temperature Range, °C
- Phase

**Armor Plate Impact Test:** 50/50

**60 mm Mortar Projectile:**
- 50% Inert, Velocity, ft/sec 170
- Aluminum Fineness

**500-lb General Purpose Bombs:**

Plate Thickness, inches

1
1¼
1½
1¾

**Bomb Drop Test:**

**T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:**

Max Safe Drop, ft

**500-lb General Purpose Bomb vs Concrete:**
- Height, ft
- Trials
- Unaffected
- Low Order
- High Order

**1000-lb General Purpose Bomb vs Concrete:**
- Height, ft
- Trials
- Unaffected
- Low Order
- High Order

# Pentolite, 50/50; 10/90

**Fragmentation Test:** 50/50

**90 mm HE, M71 Projectile, Lot WC-91:**

| | |
|---|---|
| Density, gm/cc | 1.65 |
| Charge Wt, lb | 2.147 |
| **Total No. of Fragments:** | |
| For TNT | 703 |
| For Subject HE | 968 |

**3 inch HE, M42A1 Projectile, Lot KC-5:**

| | |
|---|---|
| Density, gm/cc | 1.65 |
| Charge Wt, lb | 0.872 |
| **Total No. of Fragments:** | |
| For TNT | 514 |
| For Subject HE | 650 |

**Fragment Velocity:** ft/sec

| | |
|---|---|
| At 9 ft | 2810 |
| At 25½ ft | 2580 |
| Density, gm/cc | 1.66 |

**Blast (Relative to TNT):** (e)

| | |
|---|---|
| **Air:** | |
| Peak Pressure | 105 |
| Impulse | 107 |
| Energy | -- |
| **Air, Confined:** | |
| Impulse | |
| **Under Water:** | |
| Peak Pressure | |
| Impulse | |
| Energy | |
| **Underground:** | |
| Peak Pressure | |
| Impulse | |
| Energy | |

Eutectic Temperature, °C: 76

| gm PETN/100 gm TNT | |
|---|---|
| 76°C | 13.0 |
| 95°C | 28.3 |

**Shaped Charge Effectiveness, TNT = 100:**

| | 50/50 | 10/90 | 50/50 | 25/75 |
|---|---|---|---|---|
| | Glass Cones(f) | | Steel Cones (g) | |
| Hole Volume | 157 | 105 | 149 | 119 |
| Hole Depth | 116 | 116 | 131 | 119 |

**Color:** Yellow-white

**Principal Uses:** Shaped charges, bursting charges, demolition blocks

**Method of Loading:** Cast

**Loading Density:** gm/cc

| 50/50 | 10/90 |
|---|---|
| 1.65 | 1.60 |

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | |

Compatibility with Metals:

Dry: Copper, brass, aluminum, magnesium, magnesium-aluminum alloy, mild steel coated with acid-proof black paint, and mild steel plated with copper, cadmium or nickel are not affected. Zinc plated steel is only slightly affected.

Wet: Stainless steel, aluminum and mild steel coated with acid-proof black paint are not affected. Copper, brass, magnesium, magnesium-aluminum alloy, mild steel and mild steel plated with copper, cadmium, zinc or nickel are slightly affected.

Effect of Temperature on Rate of Detonation: (h)

| | 50/50 | |
|---|---|---|
| 16 hrs at, °C | -54 | 21 |
| Density, gm/cc | 1.67 | 1.66 |
| Rate, m/sec | 7470 | 7440 |

Preparation:

Pentolite is manufactured by either the slurry method or coprecipitation of PETN and TNT. In the slurry method PETN, in water, is stirred and heated above 80°C. TNT is added and when molten, it coats the particles of PETN. The slurry is cooled with rapid stirring and the separated granules are collected on a filter and dried below 75°C.

In coprecipitation, PETN and TNT are dissolved separately in acetone. The solutions are mixed and the explosives are precipitated simultaneously by pouring the mixed solution into cold water under vigorous agitation. The precipitated solid is collected on a filter and dried in air.

Origin:

Standardized during World War II, with the 50-50 PETN/TNT mixture being the more important for bursting charges and booster-surround charges.

References:[56]

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.

(c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(d) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

(e) W. R. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Tech Div Lecture, 9 April 1948.

(f) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition, NDRC Contract W672-ORD-5723.

(g) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Final Report, Contract W-672-ORD-5723, E. Lab, du Pont, 18 September 1943.

(h) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Different Temperatures, PATR No. 2383, November 1956.

(i) Also see the following Picatinny Arsenal Technical Report on Pentolite:

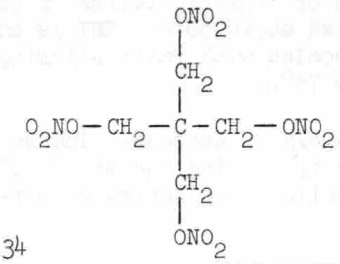
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 1360 | 1291 | 1212 | 1133 | 1284 | 1325 | 1436 | 1477 | 1388 |
| 1420 | 1451 | 1262 | 1193 | 2004 | | 1466 | 1677 | 1598 |
| 1570 | 1651 | 1372 | 1213 | | | 1796 | 1737 | 1668 |
| | | | 1363 | | | | | 1838 |

[56]See footnote 1, page 10.

# PETN (Pentaerythritol Tetranitrate)

**Composition:**

| | % |
|---|---|
| C | 19.0 |
| H | 2.5 |
| N | 17.7 |
| O | 60.8 |
| C/H Ratio | 0.134 |



**Molecular Weight:** $(C_5H_8N_4O_{12})$ 316

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -10 |
| CO % | 15 |

**Density:** gm/cc Crystal 1.77

**Melting Point:** °C 141

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^D$ $n_{25}^D$ $n_{30}^D$

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 17 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 6 |
| Sample Wt, mg | 16 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Crackles |
| Fiber Shoe | Unaffected |

**Vacuum Stability Test:**

| cc/40 Hrs, at | |
|---|---|
| 90°C | |
| 100°C | 0.5 |
| 120°C | 11+ |
| 135°C | |
| 150°C | |

**Rifle Bullet Impact Test:** 5 Trials *

| | % |
|---|---|
| Explosions | 100 |
| Partials | 0 |
| Burned | 0 |
| Unaffected | 0 |

*4.86% moisture in samples

**200 Gram Bomb Sand Test:**

Sand, gm 62.7

**Explosion Temperature:**

| Seconds, 0.1 (no cap used) | °C 272 |
|---|---|
| 1 | 244 |
| 5 Decomposes | 225 |
| 10 | 211 |
| 15 | -- |
| 20 | -- |

**Sensitivity to Initiation:**

Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | 0.17* |
| Lead Azide | 0.03* |
| Tetryl | -- |

*Alternative initiating charges.

**75°C International Heat Test:**

% Loss in 48 Hrs 0.02

**Ballistic Mortar, % TNT:** (a) 145

**Trauzl Test, % TNT:** (b) 173

**Plate Dent Test:** (c)

| | |
|---|---|
| Method | A |
| Condition | Pressed |
| Confined | Yes |
| Density, gm/cc | 1.50 |
| Brisance, % TNT | 129 |

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.1 |
| % Loss, 2nd 48 Hrs | 0.0 |
| Explosion in 100 Hrs | None |

**Detonation Rate:**

| | |
|---|---|
| Confinement | None |
| Condition | Pressed |
| Charge Diameter, in. | 1.00 |
| Density, gm/cc | 1.70 |
| Rate, meters/second | 8300 |

**Flammability Index:** Will not continue to burn

**Hygroscopicity:** % 30°C, 90% RH 0.0

**Volatility:** 0.0

# PETN (Pentaerythritol Tetranitrate)

**Booster Sensitivity Test:** (c)

| | |
|---|---|
| Condition | Pressed |
| Tetryl, gm | 5 |
| Wax, in. for 50% Detonation | |
| Wax, gm | 3 |
| Density, gm/cc | 1.6 |

**Heat of:**

| | |
|---|---|
| Combustion, cal/gm | 1960 |
| Explosion, cal/gm | 1385 |
| Gas Volume, cc/gm | 790 |
| Formation, cal/gm | 383 |
| Fusion, cal/gm | |

**Specific Heat:** cal/gm/°C (d)

| | |
|---|---|
| Room Temperature | 0.26 |

**Burning Rate:**
cm/sec

**Thermal Conductivity:**
cal/sec/cm/°C

**Coefficient of Expansion:**
Linear, %/°C

Volume, %/°C

**Hardness, Mohs' Scale:** 1.9

**Young's Modulus:**
E', dynes/cm²
E, lb/inch²
Density, gm/cc

**Compressive Strength:** lb/inch²

**Vapor Pressure:**

| °C | mm Mercury |
|---|---|

**Decomposition Equation:**

| | (e) | (e) | (f) |
|---|---|---|---|
| Oxygen, atoms/sec (Z/sec) | $10^{19.8}$ | $10^{20.6}$ | $10^{23.1}$ |
| Heat, kilocalorie/mole (ΔH, kcal/mol) | 47.0 | 50.9 | 52.3 |
| Temperature Range, °C | 161-233 | 108-120 | 137-157 |
| Phase | Liquid | Solid | At melting point |

**Armor Plate Impact Test:**

**60 mm Mortar Projectile:**
50% Inert, Velocity, ft/sec
Aluminum Fineness

**500-lb General Purpose Bombs:**

Plate Thickness, inches

1
1¼
1½
1¾

**Bomb Drop Test:**

**T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:**

Max Safe Drop, ft

**500-lb General Purpose Bomb vs Concrete:**

Height, ft
Trials
Unaffected
Low Order
High Order

**1000-lb General Purpose Bomb vs Concrete:**

Height, ft
Trials
Unaffected
Low Order
High Order

# PETN (Pentaerythritol Tetranitrate)

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**Fragment Velocity:** ft/sec

At 9 ft

At 25½ ft

Density, gm/cc

**Blast (Relative to TNT):**

**Air:**

Peak Pressure

Impulse

Energy

**Air, Confined:**

Impulse

**Under Water:**

Peak Pressure

Impulse

Energy

**Underground:**

Peak Pressure

Impulse

Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** White

**Principal Uses:**

Class A - Detonating fuse and boosters
Class B - Priming compositions

**Method of Loading:**

**Loading Density:** gm/cc

| psi x $10^3$ | 3 | 5 | 10 | 20 | 30 | 40 |
|---|---|---|---|---|---|---|
| | 1.37 | 1.58 | 1.64 | 1.71 | 1.73 | 1.74 |

**Storage:**

| | |
|---|---|
| Method | Wet |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group M (wet) |
| Exudation | None |

| | |
|---|---|
| Bulk Modulus at Room Temperature (25°-30°C): | (i) |
| Dynes/$cm^2$ x $10^{-10}$ | 4.60 |
| Density, gm/cc | 1.77 |

Compatibility with Metals:

Dry: Copper, brass, aluminum, magnesium, magnesium-aluminum alloy, stainless steel, mild steel, mild steel coated with acid-proof black paint and mild steel plated with copper, cadmium, nickel or zinc are not affected.

Wet: Stainless steel is unaffected and aluminum only vary slightly so after prolonged storage. Copper, brass, magnesium, magnesium-aluminum alloy, mild steel, mild steel coated with acid-proof black paint and mild steel plated with cadmium, copper, nickel or zinc are affected.

Sensitivity of PETN to electrostatic discharge, joules; Through 100 Mesh: (g)

| | |
|---|---|
| Unconfined | 0.06 |
| Confined | 0.21 |

Solubility, grams of PETN per 100 grams (%) of: (h)

| Trichlorethylene or Alcohol | | Acetone | | Benzene | | Toluene | |
|---|---|---|---|---|---|---|---|
| °C | % | °C | % | °C | % | °C | % |
| 0 | 0.070 | 0 | 14.37 | 0 | 0.150 | 0 | 0.150 |
| 20 | 0.195 | 20 | 24.95 | 20 | 0.450 | 20 | 0.430 |
| 40 | 0.415 | 40 | 30.56 | 40 | 1.160 | 40 | 0.620 |
| 60 | 1.205 | 60 | 42.68 | 80 | 7.900 | 60 | 2.490 |
| | | | | | | 80 | 5.850 |
| | | | | | | 100 | 15.920 |
| | | | | | | 112 | 30.900 |

| Methyl acetate | | Ether | | β-Ethoxy-ethyl-acetate | | Chlorobenzene | |
|---|---|---|---|---|---|---|---|
| °C | % | °C | % | °C | % | °C | % |
| 20 | 13 | 0 | 0.200 | 20 | 1.5 | 20 | 0.35 |
| 30 | 17 | 20 | 0.340 | 30 | 4.1 | 30 | 2.8 |
| 40 | 22 | 34.7 | 0.450 | 40 | 7.6 | 40 | 6.1 |
| 50 | 31 | | | 50 | 11.2 | 50 | 9.2 |
| | | | | 60 | 14.2 | 60 | 12.2 |

| Ethylenedichloride | | Methanol | | Tetrachloroethane | | Carbon tetrachloride | |
|---|---|---|---|---|---|---|---|
| °C | % | °C | % | °C | % | °C | % |
| 10 | 0.9 | 20 | 0.46 | 20 | 0.18 | 20 | 0.096 |
| 30 | 1.5 | 40 | 1.15 | 30 | 0.27 | 30 | 0.108 |
| 50 | 2.6 | 60 | 2.6 | 40 | 0.40 | 40 | 0.118 |
| | | | | 50 | 0.58 | 50 | 0.121 |

## PETN (Pentaerythritol Tetranitrate)

| Isopropanol | | Isobutanol | | Chloroform | | TNT | |
|---|---|---|---|---|---|---|---|
| °C | % | °C | % | °C | % | °C | % |
| 15 | 0.02 | 20 | 0.27 | 20 | 0.09 | 80 | 19.3 |
| 20 | 0.04 | 30 | 0.31 | | | 85 | 25.0 |
| 30 | 0.15 | 40 | 0.39 | | | 90 | 32.1 |
| 40 | 0.36 | 50 | 0.52 | | | 95 | 39.5 |
| 50 | 0.46 | | | | | 100 | 48.6 |
| | | | | | | 105 | 58.2 |
| | | | | | | 110 | 70.0 |
| | | | | | | 115 | 87.8 |
| | | | | | | 120 | 115 |
| | | | | | | 125 | 161 |

Eutetic of the system PETN-TNT is about 13% PETN and 87% TNT at 76°C.

Preparation:

(Nitroglycerin and Nitroglycerin Explosives, Naoum)

$$8HCHO + CH_3CHO + Ca(OH)_2 \longrightarrow 2C(CH_2OH)_4 + Ca(HCOO)_2$$

$$C(CH_2OH)_4 + 4HNO_3 \longrightarrow C(CH_2ONO_2)_4 + 4H_2O$$

1. In this preparation 1940 gm of formaldehyde and 600 gm of aceteldehyde are dissolved in 90 liters of water containing 1600 gm suspended slaked lime. The reaction is complete in about 3 weeks if agitated several times a day. The solution is filtered, the calcium formate precipitated with oxalic acid, filtered off, and the water removed under reduced pressure. On cooling the mother liquor about 1200 gm crude pentaery-thritol, melting point 235°-240°C are obtained. Purification is readily effected by stirring with a little alcohol, filtering and recrystallization from water.

2. To 400 cc of strong white nitric acid, are added 100 gm of pentaerythritol (through 50 mesh), at 5°C or below, under good agitation. After addition is complete stirring, at 5°C, is continued for 15 minutes. The mixture is drowned in 3 liters of ice-water, filtered, the product washed free of acid with water and then digested 1 hour in 1 liter of hot 0.5% sodium carbonate solution. The product is filtered, and recrystallized from acetone.

Origin:

PETN was known as an explosive in 1894 when it was proposed as an addition to smokeless powders to raise their flammability and ease of combustion (German Patent 81,664 (1894). Modern methods of preparation are described by Vignon and Gerin (Compt rend 133, 590 (1901) and German Patent 265,025 (1912) and A. Stettbacher (Z ges Schiess - Sprengstoffw 11, 112, 182 (1916) and 24, 259 (1929)). PETN was not used on a practical basis until after World War I.

Destruction by Chemical Decomposition:

PETN is decomposed by dissolving in 8 times its weight of technical grade acetone and burning the solution in a shallow container. If preferred, warm the acetone solution to 40°C, stir and add 7 parts by weight, to each part of PETN, of a solution of 1 part sodium sulfide ($Na_2S \cdot 9H_2O$) in 2 parts water heated to 80°C. The aqueous solution should be added at such a rate that the acetone solution does not boil. After mixing is complete continue stirring for one-half hour.

References:[57]

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) Ph. Naoum, Z ges Schiess - Sprengstoffw, pp. 181, 229, 267 (27 June 1932).

(c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(d) International Critical Tables.

(e) M. A. Cook and M. T. Abegg, "Isothermal Decomposition of Explosives," University of Utah, Ind & Eng Chem, (June 1956), pp. 1090-1095.

(f) A. J. B. Robertson, "The Thermal Decomposition of Pentaerythritol Tetranitrate, Nitroglycerin, Ethylenediamine Dinitrate and Ammonium Nitrate," J Chem Ind 67, 221 (1948).

(g) F. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U.S. Dept of Int, Bureau of Mines, RI 3852, 1946.

(h) Various sources in the open literature.

(i) W. S. Cramer, Bulk Compressibility Data on Several High Explosives, NAVORD Report No. 4380, 15 September 1956.

(j) Also see the following Picatinny Arsenal Technical Reports on PETN:

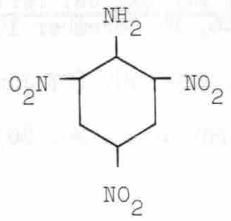
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 760 | 1041 | 772 | 843 | 904 | 1305 | 1246 | 407 | 318 | 1379 |
| 1170 | 1311 | 922 | 863 | 1274 | 1325 | 1276 | 527 | 838 | 1429 |
| 1260 | 1381 | 1182 | 1063 | 1284 | 1445 | 1316 | 857 | 1238 | 1489 |
| 1290 | 1451 | 1192 | 1133 | 1414 | 1705 | 1376 | 1247 | 1318 | 1559 |
| 1300 | 1561 | 1212 | 1253 | | 1885 | 1446 | 1517 | 1388 | 2179 |
| 1320 | 1611 | 1262 | 1343 | | 2125 | 1456 | 1617 | 1568 | |
| 1360 | 1651 | 1342 | 1493 | | | 1466 | 1737 | 1598 | |
| 1380 | | 1352 | 1533 | | | 1556 | 1797 | 1838 | |
| 1390 | | 1372 | | | | 1796 | | 2178 | |
| 1430 | | 1452 | | | | | | | |
| 1450 | | | | | | | | | |
| 1570 | | | | | | | | | |

[57]See footnote 1, page 10.

# Picramide (TNA) (2,4,6-Trinitroaniline)

**Composition:**

| | % |
|---|---|
| C | 31.5 |
| H | 1.8 |
| N | 24.5 |
| O | 42.2 |




C/H Ratio 0.500

**Impact Sensitivity, 2 Kg Wt:**
Bureau of Mines Apparatus, cm
Sample Wt 20 mg
Picatinny Arsenal Apparatus, in. 23
Sample Wt, mg 20

**Friction Pendulum Test:**
Steel Shoe
Fiber Shoe

**Rifle Bullet Impact Test:** Trials
%
Explosions
Partials
Burned
Unaffected

**Explosion Temperature:** °C
Seconds, 0.1 (no cap used)
1
5
10
15
20

**75°C International Heat Test:**
% Loss in 48 Hrs

**100°C Heat Test:**
% Loss, 1st 48 Hrs
% Loss, 2nd 48 Hrs
Explosion in 100 Hrs

**Flammability Index:**

**Hygroscopicity:** %

**Volatility:**

**Molecular Weight:** ($C_6H_4N_4O_6$) 228

**Oxygen Balance:**
$CO_2$ % -56
CO % -14

**Density:** gm/cc Crystal 1.76

**Melting Point:** °C 189 to 190

**Freezing Point:** °C

**Boiling Point:** °C Decomposes before boiling point

**Refractive Index,** $n_{20}^{D}$
$n_{25}^{D}$
$n_{30}^{D}$

**Vacuum Stability Test:**
cc/40 Hrs, at
90°C ----
100°C 0.9
120°C
135°C
150°C

**200 Gram Bomb Sand Test:**
Sand, gm 48.1

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm
Mercury Fulminate ----
Lead Azide 0.30
Tetryl ----

**Ballistic Mortar, % TNT:** 100

**Trauzl Test, % TNT:** 107

**Plate Dent Test:**
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**Detonation Rate:**
Confinement None
Condition Pressed
Charge Diameter, in. 0.5
Density, gm/cc 1.72
Rate, meters/second 7300

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Yellow

**Principal Uses:** High temperature heat resistant explosive

**Method of Loading:** Pressed

**Loading Density:** gm/cc
At 50,000 psi 1.72

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | None |

Solubility:

Insoluble in water, slightly soluble in alcohol and ether. Soluble in hot glacial acetic acid, hot ethyl acetate and in benzene and acetone.

Heat of:

| | | |
|---|---|---|
| Combustion, cal/gm | (a) | 2962 |
| Explosion, cal/gm | | 564 |
| Formation, cal/gm | (a) | 131 |

## Picramide (TNA) (2,4,6-Trinitroaniline)

Preparation:

Five grams of picryl chloride were dissolved in 180 milliliters of absolute methanol. The solution was then saturated with anhydrous, gaseous ammonia. The time required was approximately 30 minutes. The amino derivative precipitated in 78% yield (3.6 gm) melting at 190°C (literature MP 189°C).

Origin:

Picramide (2,4,6-trinitroaniline) was first prepared in 1854 by Pisani who treated picryl chloride with ammonium carbonate (CR 39, 853). The use of picramide, as a brisant explosive, was patended by Chemische Fabrik Griesheim 26 May 1894 (German Patent 84,628). Meisenheimer and Patzig reacted trinitrobenzene with hydroxylamine in cold alcohol solution to obtain picramide (Ber 39, 2534 (1906)). Witt and Witte obtained the compound by nitrating a solution of aniline in glacial acetic acid or concentrated $H_2SO_4$ at about 5°C with concentrated $HNO_3$ (Ber 41, 3091 (1908)). Holleman gives details of the prep ation from p-nitroaniline and from acetanilide (Rec trav chim 49, 112 (1930)).

Reference:[58]

(a) William H. Rinkenbach, "The Heats of Combustion and Formation of Aromatic Nitro Compounds," J Am Chem Soc 52, 116 (1930).

[58]See footnote 1, page 10.

**Composition:**

| | % |
|---|---|
| Explosive D | 52 |
| TNT | 48 |

C/H Ratio

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 100+ |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 17 |
| Sample Wt, mg | 19 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | Unaffected |

**Rifle Bullet Impact Test:** Trials

| | % |
|---|---|
| Explosions | 0 |
| Partials | 0 |
| Burned | 40 |
| Unaffected | 60 |

**Explosion Temperature:** °C

| | | |
|---|---|---|
| Seconds, 0.1 | (no cap used) | 456 |
| 1 | | 354 |
| 5 | Decomposes | 285 |
| 10 | | 265 |
| 15 | | 260 |
| 20 | | 255 |

**75°C International Heat Test:**

% Loss in 48 Hrs 0.0

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.0 |
| % Loss, 2nd 48 Hrs | 0.05 |
| Explosion in 100 Hrs | None |

**Flammability Index:**

**Hygroscopicity:** % 30°C, 90% RH 0.02

**Volatility:**

**Molecular Weight:** 236

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -63 |
| CO % | -19 |

**Density:** gm/cc Cast 1.62

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$

$n_{25}^{D}$

$n_{30}^{D}$

**Vacuum Stability Test:**

cc/40 Hrs, at

| | |
|---|---|
| 90°C | |
| 100°C | 0.37 |
| 120°C | 0.68 |
| 135°C | -- |
| 150°C | 0.7 |

**200 Gram Bomb Sand Test:**

Sand, gm 45.0

**Sensitivity to Initiation:**

Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | |
| Lead Azide | 0.20 |
| Tetryl | 0.05 |

**Ballistic Mortar, % TNT:** (a) 100

**Trauzl Test, % TNT:**

**Plate Dent Test:** (b)

| | |
|---|---|
| Method | B |
| Condition | Cast |
| Confined | No |
| Density, gm/cc | 1.63 |
| Brisance, % TNT | 100 |

**Detonation Rate:** (b)

| | |
|---|---|
| Confinement | None |
| Condition | Cast |
| Charge Diameter, in. | 1.0 |
| Density, gm/cc | 1.63 |
| Rate, meters/second | 6970 |

# Picratol, 52/48

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

| | |
|---|---|
| Density, gm/cc | 1.61 |
| Charge Wt, lb | 2.075 |
| **Total No. of Fragments:** | |
| For TNT | 703 |
| For Subject HE | 769 |

**3 inch HE, M42A1 Projectile, Lot KC-5:**

| | |
|---|---|
| Density, gm/cc | 1.61 |
| Charge Wt, lb | 0.850 |
| **Total No. of Fragments:** | |
| For TNT | 514 |
| For Subject HE | 487 |

**Fragment Velocity:** ft/sec

| | |
|---|---|
| At 9 ft | 2590 |
| At 25½ ft | 2320 |
| Density, gm/cc | 1.62 |

**Blast (Relative to TNT):**

| | |
|---|---|
| **Air:** | |
| Peak Pressure | 100 |
| Impulse | 100 |
| Energy | -- |
| **Air, Confined:** | |
| Impulse | |
| **Under Water:** | |
| Peak Pressure | |
| Impulse | |
| Energy | |
| **Underground:** | |
| Peak Pressure | |
| Impulse | |
| Energy | |

Bomb Drop Test:

T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:

Max Safe Drop, ft 10,000-12,000

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Brown-yellow

**Principal Uses:** AP, SAP projectiles and bombs

**Method of Loading:** Cast

**Loading Density:** gm/cc 1.62

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | None at 65°C |

Preparation:

Picratol is made by heating TNT to about 90°C in a steam-jacketed melt kettle. Explosive D is added slowly, without preheating, and the mixture stirred until uniform in composition. This slurry is cooled to about 85°C and poured into the appropriate ammunition component.

Origin:

Developed during World War II as an insensitive, melt-loaded AP bomb and projectile filler.

Booster Sensitivity Test: (c)

| | |
|---|---|
| Condition | Cast |
| Tetryl, gm | 100 |
| Wax, in. for 50% Detonation | 1.00 |
| Density, gm/cc | 1.63 |

References:[59]

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(c) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

(d) R. W. Drake, Fragment Velocity and Panel Penetration of Several Explosives in Simulated Shells, OSRD Report No. 5622, 2 January 1946.

(e) Also see the following Picatinny Arsenal Technical Reports on Picratol:

| 0 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|
| 1470 | 1885 | 1466<br>1796<br>1956 | 1737<br>1797 | 1838 | 1729 |

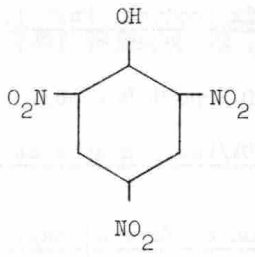
[59]See footnote 1, page 10.

# Picric Acid

**Composition:**

| | % |
|---|---|
| C | 31.5 |
| H | 1.3 |
| N | 18.3 |
| O | 48.9 |

C/H Ratio 0.656




**Molecular Weight:** $(C_6H_3N_3O_7)$ 229

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -45 |
| CO % | -3.5 |

**Density:** gm/cc Crystal 1.76

**Melting Point:** °C 122

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^D$ $n_{25}^D$ $n_{30}^D$

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 85 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 13 |
| Sample Wt, mg | 17 |

**Friction Pendulum Test:**

Steel Shoe

Fiber Shoe

**Vacuum Stability Test:**

cc/40 Hrs, at

| | |
|---|---|
| 90°C | |
| 100°C | 0.2 |
| 120°C | 0.5 |
| 135°C | |
| 150°C | |

**Rifle Bullet Impact Test:** Trials

| | % |
|---|---|
| Explosions | 0 |
| Partials | 60 |
| Burned | 40 |
| Unaffected | 0 |

**200 Gram Bomb Sand Test:**

Sand, gm 48.5

**Explosion Temperature:** °C

Seconds, 0.1 (no cap used)

| | |
|---|---|
| 1 | |
| 5 Decomposes | 320 |
| 10 | |
| 15 | |
| 20 | |

**Sensitivity to Initiation:**

Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | 0.26* |
| Lead Azide | 0.24* |
| Tetryl | |

*Alternative initiating charges.

**Ballistic Mortar, % TNT:** (a) 112

**Trauzl Test, % TNT:** (b) 101

**75°C International Heat Test:**

% Loss in 48 Hrs 0.05

**Plate Dent Test:** (c)

| | |
|---|---|
| Method | A |
| Condition | Pressed |
| Confined | No |
| Density, gm/cc | 1.50 |
| Brisance, % TNT | 107 |

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.03 |
| % Loss, 2nd 48 Hrs | 0.09 |
| Explosion in 100 Hrs | None |

**Detonation Rate:** (d)

| Confinement | Unconfined | |
|---|---|---|
| Condition | Pressed | Cast |
| Charge Diameter, in. | 1.0 | 1.25 |
| Density, gm/cc | 1.64 | 1.71 |
| Rate, meters/second | 5270 | 7350 |

**Flammability Index:**

**Hygroscopicity:** % 30°C, 90% RH 0.04

**Volatility:**

**Booster Sensitivity Test:** (c)

| Condition | Pressed | Cast |
|---|---|---|
| Tetryl, gm | 10 | 5 |
| Wax, in. for 50% Detonation | | |
| Wax, gm | 2 | 0 |
| Density, gm/cc | 1.6 | 1.7 |

**Heat of:**

| | |
|---|---|
| Combustion, cal/gm | 2672 |
| Explosion, cal/gm | 1000 |
| Gas Volume, cc/gm | 675 |
| Formation, cal/gm | 248 |
| Fusion, cal/gm (e) | 20.4 |
| Temperature, °C | 122 |

**Specific Heat:** cal/gm/°C (e)

| °C | |
|---|---|
| 0 | 0.235 |
| 30 | 0.258 |
| 60 | 0.282 |
| 90 | 0.310 |
| 120 | 0.337 |

**Burning Rate:**
cm/sec

**Thermal Conductivity:** (f)

| | |
|---|---|
| cal/sec/cm/°C | $6.24 \times 10^{-4}$ |
| Density, gm/cc | 1.406 |

**Coefficient of Expansion:**
Linear, %/°C

Volume, %/°C

**Hardness, Mohs' Scale:** 2.1

**Young's Modulus:**
E', dynes/cm²
E, lb/inch²
Density, gm/cc

**Compressive Strength:** lb/inch²

**Vapor Pressure:**

| °C | mm Mercury |
|---|---|
| 195 | 2 |
| 255 | 50 |

**Decomposition Equation:**
Oxygen, atoms/sec (Z/sec)
Heat, kilocalorie/mole (ΔH, kcal/mol)
Temperature Range, °C
Phase

**Armor Plate Impact Test:**

**60 mm Mortar Projectile:**
50% Inert, Velocity, ft/sec
Aluminum Fineness

**500-lb General Purpose Bombs:**

Plate Thickness, inches

1
1¼
1½
1¾

**Bomb Drop Test:**

**T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:**

Max Safe Drop, ft

**500-lb General Purpose Bomb vs Concrete:**

Height, ft
Trials
Unaffected
Low Order
High Order

**1000-lb General Purpose Bomb vs Concrete:**

Height, ft
Trials
Unaffected
Low Order
High Order

# Picric Acid

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Yellow

**Principal Uses:** Formerly projectile filler, now explosive admixture; and for the manufacture of Explosive D

**Method of Loading:** Pressed

**Loading Density:** gm/cc

| psi x $10^3$ | | | | | |
|---|---|---|---|---|---|
| 3 | 5 | 10 | 12 | 15 | 20 |
| 1.40 | 1.50 | 1.57 | 1.59 | 1.61 | 1.64 |

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | None |

# Picric Acid

**Solubility: grams per 100 grams (%) of:** (g)

| Water | | Alcohol | | Benzene | | Toluene | | Ether | |
|---|---|---|---|---|---|---|---|---|---|
| °C | % | °C | % | °C | % | °C | % | °C | % |
| 0 | 0.85 | 0 | 4.5 | 0 | ~2 | 20 | ~13 | 20 | ~3 |
| 20 | 1.17 | 20 | 6.9 | 20 | 9.6 | 60 | ~30 | 34.7 | 3.96 |
| 40 | 1.88 | 40 | 12.0 | 40 | 27.5 | | | | |
| 60 | 2.98 | | | 60 | 59 | | | | |
| 80 | 4.53 | | | | | | | | |
| 100 | 7.1 | | | | | | | | |

| Chloroform | | Ethyl acetate | | Carbon tetrachloride | | Pyridine | | Acetone | |
|---|---|---|---|---|---|---|---|---|---|
| °C | % | °C | % | °C | % | °C | % | °C | % |
| 20 | ~2 | 20 | 42 | 20 | ~0.07 | 10 | 24 | 20 | 125 |
| 60 | ~6 | 30 | 50 | 60 | ~0.4 | 30 | 37.5 | 30 | 137 |
| | | 40 | 58 | | | 50 | 58 | 40 | 164 |
| | | 50 | 69 | | | | | 50 | 208 |

| Methanol | | Isopropyl alcohol | | Propanol-1 | | Carbon disulfide | |
|---|---|---|---|---|---|---|---|
| °C | % | °C | % | °C | % | °C | % |
| 0 | 14 | 10 | 6.4 | 0 | 2.4 | 20 | 0.12 |
| 20 | 19 | 30 | 9.8 | 20 | 3.3 | 30 | 0.16 |
| 40 | 31 | 50 | 15.5 | 40 | 5.4 | | |
| 50 | 41 | | | 50 | 7.4 | | |

**Preparation:** (Summary Report of NDRC, Div 8, Vol I)

$$C_6H_6 + Hg(NO_3)_2 \longrightarrow C_6H_5HgNO_3 + HNO_3 \quad (1)$$

$$C_6H_5HgNO_3 + N_2O_4 \longrightarrow C_6H_5NO + Hg(NO_3)_2 \quad (2)$$

$$C_6H_5NO + 2NO \longrightarrow C_6H_5N_2NO_3 \quad (3a)$$

$$C_6H_5N_2NO_3 + H_2O \longrightarrow C_6H_5OH + N_2 + HNO_3 \quad (3b)$$

$$C_6H_5OH + HNO_3 \xrightarrow{NO_2} O_2NC_6H_4OH + H_2O \quad (3c)$$

$$C_6H_5NO \xrightarrow[\text{oxidation and rearrangement}]{HNO_3} O_2NC_6H_4OH \quad (4)$$

$$O_2NC_6OH + HNO_3 \xrightarrow{NO_2} (O_2N)_2C_6H_3OH + H_2O \quad (5)$$

$$(O_2N)_2C_6H_3OH + HNO_3 \xrightarrow{NO_2} (O_2N)_3C_6H_2OH + H_2O \quad (6)$$

The two variables of greatest importance in this process are nitric acid concentration and the effective concentration of benzene (i.e., benzene dissolved in the oxynitration solution). The optimal concentration of nitric acid is in the range 10.4 to 11.6 molar (or the equivalent of 50% to 55% by weight for pure acid). The acid concentration greatly influences the over all rate of reaction, below 10.4 molar the rate falls off rapidly, while above 10.4 molar the rates of both the oxynitration reaction and various side reactions, such as direct nitration, increase rapidly. The range mentioned above seems, in general, to give the lowest proportion of neutral nitro-compounds to nitro-phenols with, at the same time, an adequate rate of oxynitration. The oxynitration solution must be fortified frequently, or, preferably, continuously with nitric acid. Strengths of nitric acid between 95% and 98% are best, due to the smaller increase in reaction volume than if weaker acid were used. The use of absolute nitric acid requires that its direct contact with liquid benzene be avoided.

The effective concentration of benzene is probably the most critical variable affecting the proportion of neutral nitro-compounds to nitrophenols and amounts of colored by-products. Saturation of the oxynitration solution with benzene is undesirable and thus in batch processes slow benzene addition is preferable to the addition of it in one portion; in continuous processes where an excess of benzene is used the rate of agitation is important.

The concentration of mercuric nitrate catalyst does not appear to be a critical factor over a fairly wide range. Concentrations of 0.37 to 0.5 mole of mercuric nitrate per liter of oxynitration solution have been found to give satisfactory results in most cases.

A continuous process, known as the continuous solution process, works on the following cycle. The oxynitration solution is saturated with benzene by vigorous agitation with excess benzene at room temperature, the saturated solution is separated from excess benzene and circulated through a heated coil; it is then cooled to room temperature and agitated again, with benzene, which extracts the organic product and resaturates the oxynitration solution. In evaluating this process, the rate of formation of dinitrophenol per liter of reacting solution in the coil is determined; 70 gm of dinitrophenol per liter per hour is representative performance. The dinitrophenol is, of course, nitrated to picric acid.

Origin:

Picric Acid was first prepared in 1771 by Woulff who found the reaction of nitric acid and indigo yielded a dye. Hausmann isolated Picric Acid in 1778 and studied it further (Journal de physique 32, 165 (1788)). The preparation was studied by many chemists but in 1841 Laurent established its identity (Ann chim phys III, 3, 221 (1841)). It was used as a yellow dye until Turpin, in 1885, proposed Picric Acid as a bursting charge for high explosive shell (French Patent 167,512). The British adopted Picric Acid as a military explosive in 1888 under the name of lyddite and other nations soon began to use it as the first melt-loaded high explosive. Mixtures of other explosives and Picric Acid were developed until it was gradually replaced by TNT about 1900. Today Picric Acid is used for the manufacture of Explosive D.

Destruction by Chemical Decomposition:

Picric Acid is decomposed by dissolving in 25 times its weight of a solution made from 1 part sodium hydroxide and 21 parts sodium sulfide ($Na_2S \cdot 9H_2O$) in 200 parts of water. Some hydrogen sulfide and ammonia are evolved.

References:[60]

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) Ph. Naoum, Z ges Schiess-Sprengstoffw, pp. 181, 229, 267 (27 June 1932).

(c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(d) G. H. Messerly, The Rate of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.

M. D. Hurwitz, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1946.

(e) International Critical Tables.

(f) E. Hutchinson, The Thermal Sensitiveness of Explosives. The Thermal Conductivity Explosive Materials, AC Report No. 2861, First Report, August 1942.

(g) Values taken from various sources in the open literature.

(h) Also see the following Picatinny Arsenal Technical Reports on Picric Acid:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| 1651 | 132 | 1383 | 694 | 65 | 266 | 1347 | 1118 | 1549 |
| | 582 | | 764 | 425 | 556 | 1557 | | |
| | 1172 | | 874 | 1585 | 926 | | | |
| | 1352 | | | | 976 | | | |
| | 1372 | | | | 986 | | | |
| | | | | | 1446 | | | |
| | | | | | 1556 | | | |

[60] See footnote 1, page 10.

**Composition:**

| | % |
|---|---|
| PETN | 81 |
| Gulf Crown E Oil | 19 |
| C/H Ratio | |

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 11 |
| Sample Wt, mg | 27 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | Unaffected |

**Rifle Bullet Impact Test:**

| | Trials % |
|---|---|
| Explosions | 0 |
| Partials | 0 |
| Burned | 0 |
| Unaffected | 100 |

**Explosion Temperature:** °C

Seconds, 0.1 (no cap used)

| | |
|---|---|
| 1 | |
| 5 | Decomposes* |
| 10 | |
| 15 | |
| 20 | |

*No value obtained.

**75°C International Heat Test:**

% Loss in 48 Hrs

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.17 |
| % Loss, 2nd 48 Hrs | 0.00 |
| Explosion in 100 Hrs | None |

**Flammability Index:**

**Hygroscopicity:** % 30°C, 90% RH 0.02

**Volatility:**

**Molecular Weight:** 310

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -74 |
| CO % | -31 |

**Density:** gm/cc Hand tamped 1.35

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Vacuum Stability Test:**

cc/40 Hrs, at

| | | |
|---|---|---|
| 90°C | | |
| 100°C | | 0.48 |
| 120°C | 16 hours | 11+ |
| 135°C | | |
| 150°C | | |

**200 Gram Bomb Sand Test:**

Sand, gm 41.6

**Sensitivity to Initiation:**

Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | 0.20* |
| Lead Azide | 0.20* |
| Tetryl | |

*Alternative initiating charges.

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**Plate Dent Test:** (a)

| | |
|---|---|
| Method | B |
| Condition | Hand tamped |
| Confined | No |
| Density, gm/cc | 1.33 |
| Brisance, % TNT | 76 |

**Detonation Rate:**

| | |
|---|---|
| Confinement | None |
| Condition | Hand tamped |
| Charge Diameter, in. | 1.0 |
| Density, gm/cc | 1.37 |
| Rate, meters/second | 7075 |

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

| | |
|---|---|
| Density, gm/cc | 1.33 |
| Charge Wt, lb | 1.723 |
| **Total No. of Fragments:** | |
| For TNT | 703 |
| For Subject HE | 519 |

**3 inch HE, M42A1 Projectile, Lot KC-5:**

| | |
|---|---|
| Density, gm/cc | 1.39 |
| Charge Wt, lb | 0.735 |
| **Total No. of Fragments:** | |
| For TNT | 514 |
| For Subject HE | 428 |

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

Preparation:

PIPE is manufactured by simple mechanical mixing of PETN in oil.

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:**

**Principal Uses:** Plastic demolition explosive

**Method of Loading:** Hand tamped

**Loading Density:** gm/cc 1.35

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | |

Origin:

PIPE, a mechanical mixture of PETN and Gulf Crown E Oil, was developed in the United States during World War II.

References: 61

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III-Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) S. Livingston, Properties of Explosives RIPE, PIPE and PEP-3, Picatinny Arsenal Technical Report 1517, 24 April 1945.

[61] See footnote 1, page 10.

Plumbatol

**Composition:**
%

| | |
|---|---|
| Lead Nitrate | 70 |
| TNT | 30 |
| C/H Ratio | |

**Molecular Weight:** 291

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -5.4 |
| CO % | +9.3 |

**Density:** gm/cc

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | -- |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 13 |
| Sample Wt, mg | 22 |

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Friction Pendulum Test:**
Steel Shoe
Fiber Shoe

**Vacuum Stability Test:**
cc/40 Hrs, at
90°C
100°C
120°C
135°C
150°C

**Rifle Bullet Impact Test:** Trials / %
Explosions
Partials
Burned
Unaffected

**200 Gram Bomb Sand Test:**
Sand, gm 32.4

**Explosion Temperature:** °C
Seconds, 0.1 (no cap used)
1
5 Decomposes 238
10
15
20

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | -- |
| Lead Azide | 0.20 |
| Tetryl | 0.10 |

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**75°C International Heat Test:**
% Loss in 48 Hrs

**Plate Dent Test:**
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**100°C Heat Test:**
% Loss, 1st 48 Hrs
% Loss, 2nd 48 Hrs
Explosion in 100 Hrs

**Detonation Rate:** (b)
Confinement
Condition
Charge Diameter, in.
Density, gm/cc 2.89
Rate, meters/second 4850

**Flammability Index:**

**Hygroscopicity:** %

**Volatility:**

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

Preparation:

Plumbatol is manufactured by simple mechanical mixing of lead nitrate in molten TNT.

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones (a) |
|---|---|---|
| Hole Volume | 114 | |
| Hole Depth | 103 | |

**Color:** Light yellow

**Principal Uses:**

**Method of Loading:** Cast

**Loading Density:** gm/cc

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | |

Origin:

An explosive containing 70% lead nitrate and 30% TNT has been used in Belgium under the name of "Marcarite."

References:[62]

(a) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition, NDRC Contract W-672-ORD-5723.

(b) Thorpe's Dictionary of Applied Chemistry, Fourth Edition, Vol IV, Longmans, Green and Company, London - New York - Toronto, p. 464.

[62]See footnote 1, page 10.

**Composition:**

| % | | * |
|---|---|---|
| Nitromethane | 100 | 95 |
| Ethylenediamine | -- | 5 |

*The mixture 95/5 Nitromethane/Ethylenediamine is designated PLX (for Picatinny Liquid Explosive). See note under Storage.

C/H Ratio

**Impact Sensitivity, 2 Kg Wt:**

| | 100 | 95/5 |
|---|---|---|
| Bureau of Mines Apparatus, cm | 100+ | 100+ |
| Sample Wt 20 mg | | |
| Picatinny Arsenal Apparatus, in. | | |
| Sample Wt, mg | 20 | 20 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | Unaffected |

**Rifle Bullet Impact Test:**

| | 10 Trials % | 5 Trials % |
|---|---|---|
| Explosions | 0 | 0 |
| Partials | 0 | 0 |
| Burned | 0 | 0 |
| Unaffected | 100 | 100 |

**Explosion Temperature:**

| Seconds, 0.1 | °C 100 | °C 95/5 |
|---|---|---|
| 1 | | |
| 5 | 430 | 430 |
| 10 | | |
| 15 | | |
| 20 | | |

**75°C International Heat Test:**
% Loss in 48 Hrs

**100°C Heat Test:**
% Loss, 1st 48 Hrs
% Loss, 2nd 48 Hrs
Explosion in 100 Hrs

**Flammability Index:**

**Hygroscopicity:** %

**Volatility:**

| **Molecular Weight:** | 100 61 | 95/5 61 |
|---|---|---|
| **Oxygen Balance:** | | |
| $CO_2$ % | -39 | -48 |
| CO % | -13 | -21 |
| **Density:** gm/cc | 1.14 | 1.12 |
| **Melting Point:** °C | -29 | |
| **Freezing Point:** °C | | |
| **Boiling Point:** °C | 101 | |
| **Refractive Index,** $n_{20}^{D}$ | | |
| $n_{25}^{D}$ | | |
| $n_{30}^{D}$ | | |

**Vacuum Stability Test:**
cc/40 Hrs, at
90°C
100°C
120°C
135°C
150°C

| **200 Gram Bomb Sand Test:** | 100 | 95/5 |
|---|---|---|
| Sand, gm | 8.1 | 50.6 |

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm
Mercury Fulminate
Lead Azide
Tetryl

**Ballistic Mortar, % TNT:** 134

**Trauzl Test, %** PA 127

**Plate Dent Test:**
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

| **Detonation Rate:** | 1/32"* | 1/32"* |
|---|---|---|
| Confinement | Glass | Glass |
| Condition | Liquid | Liquid |
| Charge Diameter, in. | 1.25 | 0.94 |
| Density, gm/cc | 1.14 | 1.12 |
| Rate, meters/second | 6210 | 6165 |

*Tube wall thickness

**Booster Sensitivity Test:** Nitromethane

Condition

Tetryl, gm

Wax, in. for 50% Detonation

Wax, gm

Density, gm/cc

**Heat of:** (a)

Combustion, cal/gm 2830

Explosion, cal/gm

Gas Volume, cc/gm

Formation, cal/gm -348

Fusion, cal/gm

Vaporization, cal/gm 149

**Specific Heat:** cal/gm/°C (b)

$C_p = 0.4209 - 0.00076t + 0.0000061t^2$ for 15°C to 70°C

**Burning Rate:**

cm/sec

**Thermal Conductivity:**

cal/sec/cm/°C

**Coefficient of Expansion:**

Linear, %/°C

Volume, %/°C

**Hardness, Mohs' Scale:**

**Young's Modulus:**

E', dynes/cm²

E, lb/inch²

Density, gm/cc

**Compressive Strength:** lb/inch²

**Vapor Pressure:** (c)

| °C | mm Mercury |
|---|---|
| 70 | 258 |
| 85 | 444 |

**Decomposition Equation:** (d) Nitromethane

$10^{14.6}$

Oxygen, atoms/sec (Z/sec)

Heat, kilocalorie/mole (ΔH, kcal/mol) 56.6

Temperature Range, °C 380-430

Phase Gaseous

**Armor Plate Impact Test:**

**60 mm Mortar Projectile:**

50% Inert, Velocity, ft/sec

Aluminum Fineness

**500-lb General Purpose Bombs:**

Plate Thickness, inches

1

1¼

1½

1¾

**Bomb Drop Test:**

**T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:**

Max Safe Drop, ft

**500-lb General Purpose Bomb vs Concrete:**

Height, ft

Trials

Unaffected

Low Order

High Order

**1000-lb General Purpose Bomb vs Concrete:**

Height, ft

Trials

Unaffectea

Low Order

High Order

# PLX (Liquid)

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Light yellow

**Principal Uses:** Minefield clearing

**Method of Loading:** Pumping

| **Loading Density:** gm/cc | 100 | 95/5 |
|---|---|---|
| | 1.14 | 1.12 |

**Storage:**

Method: Components stored separately; mixed only when ready to use

Hazard Class (Quantity-Distance)

Compatibility Group

Exudation

| Minimum Propagating Thickness, in: | 100 | 95/5 |
|---|---|---|
| | 0.5 | 0.063 |

Viscosity, centipoises: (e)

| Temp, | |
|---|---|
| 10°C | 0.748 |
| 25°C | 0.625 |
| 40°C | 0.533 |

Compatibility with Metals:

Stainless steel, mild steel and duriron not affected; corrodes brass.

Origin:

Nitromethane has been known since 1872 (Kolbe, J prakt Chem (2) 5, 427 (1872), but was available only as a laboratory product until it appeared as an industrial chemical in 1940. A number of patents have been issued for nitromethane produced as a by-product of the nitration of propane (U. S. Patent 1,967,667 (1934); British Patent 443,707 (1937); and Canadian Patent 371,007 (1938).

The development of nitromethane liquid explosives was based on information that nitromethane is sensitized to initiation and propagation of detonation by the addition of various amines. This study made at Picatinny Arsenal in 1945 indicated that mixtures of nitromethane with 5% of ethylenediamine, n-butyl-amine, or morpholine showed considerable promise for application in mine-field clearance (L. H. Eriksen and J. W. Rowen, PATR No. 1565, 17 September 1945).

References:[63]

(a) D. E. Holcomb and C. F. Dorsey, "Thermodynamic Properties of Nitroparaffins," Ind Engr Chem 41, 2788 (1949).

(b) J. W. Williams, "A Study of the Physical Properties of Nitromethane," J Am Chem Soc 47, 2644 (1925).

(c) L. Medard, "Explosive Properties of Nitromethane," Mém poudr 33, 125 (1951).

(d) T. L. Cottrell, T. E. Graham and T. J. Reid, "The Thermal Decomposition of Nitromethanes," Transactions of the Faraday Society 47, 584 (1951).

(e) F. Bellinger, H. B. Friedman, W. H. Bauer, J. W. Eastes and W. C. Bull, "Chemical Propellants: Stability of Mononitromethane," Ind Engr Chem 40, 1320 (1948).

(f) Also see the following Picatinny Arsenal Technical Reports on Nitromethane:

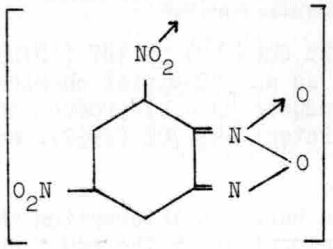
| 0 | 1 | 3 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|
| 1660 | 1681<br>1831 | 2113 | 1565 | 2016 | 1747 | 1708 | 1619 |

[63]See footnote 1, page 10.

# Potassium Dinitrobenzfuroxan (KDNBF)

**Composition:**

| | % |
|---|---|
| C | 27.3 |
| H | 0.4 |
| N | 21.2 |
| O | 36.3 |
| K | 14.8 |




C/H Ratio 0.416

**Molecular Weight:** $(KC_6H_4N_4O_6)$ 225

**Oxygen Balance:**
- $CO_2$ % -60
- CO % -18

**Density:** gm/cc 2.21

**Melting Point:** °C Explodes 210

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Impact Sensitivity, 2 Kg Wt:**
- Bureau of Mines Apparatus, cm --
  Sample Wt 20 mg
- Picatinny Arsenal Apparatus, in. 3; (1 lb wt) 6
  Sample Wt, mg 7

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Explodes |
| Fiber Shoe | Explodes |

**Vacuum Stability Test:**
cc/40 Hrs, at
- 90°C
- 100°C
- 120°C
- 135°C
- 150°C

**Rifle Bullet Impact Test:**

| | Trials | % |
|---|---|---|
| Explosions | | |
| Partials | | |
| Burned | | |
| Unaffected | | |

**200 Gram Bomb Sand Test:**

| | | |
|---|---|---|
| Sand, gm | 44.8 | 43.6 |
| Black powder fuse 9.5 | | |

**Explosion Temperature:** °C

| Seconds, 0.1 (no cap used) | -- |
|---|---|
| 1 | -- |
| 5 | 250 |
| 10 | |
| 15 | |
| 20 | |

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm

| | | |
|---|---|---|
| Mercury Fulminate | 0.30 | 0.20 |
| Lead Azide | | 0.10 |
| Tetryl | | |

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**75°C International Heat Test:**
% Loss in 48 Hrs

**Plate Dent Test:**
- Method
- Condition
- Confined
- Density, gm/cc
- Brisance, % TNT

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.03 |
| % Loss, 2nd 48 Hrs | 0.05 |
| Explosion in 100 Hrs | None |

**Detonation Rate:**
- Confinement
- Condition
- Charge Diameter, in.
- Density, gm/cc
- Rate, meters/second

**Flammability Index:**

**Hygroscopicity:** %

| | |
|---|---|
| 30°C, 75% RH | 0.11 |
| 30°C, 90% RH | 0.27 |

**Volatility:**

**Booster Sensitivity Test:**
Condition
Tetryl, gm
Wax, in. for 50% Detonation
Wax, gm
Density, gm/cc

**Heat of:**

| | |
|---|---|
| Combustion, cal/gm | 2209 |
| Explosion, cal/gm | 725 |
| Gas Volume, cc/gm | 604 |
| Formation, cal/gm | |
| Fusion, cal/gm | |

**Specific Heat:** cal/gm/°C (b)

| °C | |
|---|---|
| -50 | 0.217 |
| 0 | 0.217 |
| 25 | 0.217 |
| 50 | 0.217 |

**Burning Rate:**
cm/sec

**Thermal Conductivity:**
cal/sec/cm/°C

**Coefficient of Expansion:**
Linear, %/°C

Volume, %/°C

**Hardness, Mohs' Scale:**

**Young's Modulus:**
E', dynes/cm²
E, lb/inch²
Density, gm/cc

**Compressive Strength:** lb/inch²

**Vapor Pressure:**
°C mm Mercury

**Decomposition Equation:**
Oxygen, atoms/sec (Z/sec)
Heat, kilocalorie/mole (ΔH, kcal/mol)
Temperature Range, °C
Phase

**Armor Plate Impact Test:**

**60 mm Mortar Projectile:**
50% Inert, Velocity, ft/sec
Aluminum Fineness

**500-lb General Purpose Bombs:**

Plate Thickness, inches

1
1¼
1½
1¾

**Bomb Drop Test:**

**T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:**

Max Safe Drop, ft

**500-lb General Purpose Bomb vs Concrete:**

Height, ft
Trials
Unaffected
Low Order
High Order

**1000-lb General Purpose Bomb vs Concrete:**

Height, ft
Trials
Unaffected
Low Order
High Order

# Potassium Dinitrobenzfuroxan (KDNBF)

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Orange to brown

**Principal Uses:** Primary explosive

**Method of Loading:** Pressed

**Loading Density:** gm/cc

| psi x $10^3$ | 10 | 20 | 30 | 40 | 80 |
|---|---|---|---|---|---|
| | 1.63 | 1.77 | 1.81 | 1.86 | 1.98 |

**Storage:**

| | |
|---|---|
| Method | Wet |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group M (wet) |
| Exudation | |

Solubility in Water, gm/100 gm solvent, at:

| | |
|---|---|
| 30°C | 0.245 |

Stab Sensitivity:

| Density gm/cc | Firing Point (inch-ounces) 0% | 50% | 100% |
|---|---|---|---|
| 1.63 | 73 | 79 | 84 |
| 1.77 | 66 | 75 | 83 |
| 1.81 | 42 | 48 | 64 |
| 1.86 | 12 | 15 | 18 |
| 1.93 | 11 | 17 | 21 |
| 1.98 | 7 | 11 | 14 |

Activation Energy:

| | |
|---|---|
| kcal/mol | 82.6 |
| Induction Period, sec | 0.5-10 |

Preparation of Potassium Salt of 4,6-dinitrobenzfuroxan: (a)

Benzfuroxan, made by the reaction of ortho-nitroaniline and alkaline sodium hypochlorite, was dissolved in 6 parts of 96% sulfuric acid and nitrated at 5°-20°C with a 4 to 1 sulfuric-nitric acid mixture. The salt was prepared by neutralization of the 4,6-dinitrobenzfuroxan with potassium bicarbonate followed by recrystallization from hot water. The product forms in small golden orange plates which explode at 210°C.

Origin:

The potassium salt of 4,6-dinitrobenzfuroxan was first prepared in 1899 by von P. Drost (Ann 307, 56 (1899)).

References: [64]

(a) R. J. Gaughran, J. P. Picard and J. V. R. Kaufman, "Contribution to the Chemistry of Benzfuroxan Derivatives," J Am Chem Soc 76, 2233 (1954).

(b) C. Lenchitz, Ice Calorimeter Determination of Enthalpy and Specific Heat of Eleven Organometallic Compounds, PATR No. 2224, November 1955.

(c) Also see the following Picatinny Arsenal Technical Reports on Potassium Dinitrobenzfuroxan:

| 2 | 3 | 6 | 9 |
|---|---|---|---|
| 2122 | 2093 | 2146 | 2179 |

[64] See footnote 1, page 10.

PTX-1

| | | | |
|---|---|---|---|
| **Composition:** % | | **Molecular Weight:** | 252 |
| RDX | 30 | **Oxygen Balance:** | |
| Tetryl | 50 | $CO_2$ % | -45 |
| TNT | 20 | CO % | - 9 |
| C/H Ratio | | **Density:** gm/cc | 1.68 |
| **Impact Sensitivity, 2 Kg Wt:** | | **Melting Point:** °C Eutectic | 67 |
| Bureau of Mines Apparatus, cm | 44 | **Freezing Point:** °C | |
| Sample Wt 20 mg | | **Boiling Point:** °C | |
| Picatinny Arsenal Apparatus, in. | | **Refractive Index,** $n_{20}^{D}$ | |
| Sample Wt, mg | | $n_{25}^{D}$ | |
| **Friction Pendulum Test:** | | $n_{30}^{D}$ | |
| Steel Shoe | | **Vacuum Stability Test:** | |
| Fiber Shoe | | cc/40 Hrs, at | |
| **Rifle Bullet Impact Test:** | Trials % | 90°C | |
| Explosions | 20 | 100°C | 3.0 |
| Partials | 20 | 120°C | |
| Burned | 0 | 135°C | |
| Unaffected | 60 | 150°C | |
| **Explosion Temperature:** °C | | **200 Gram Bomb Sand Test:** | |
| Seconds, 0.1 (no cap used) | | Sand, gm | 54.8 |
| 1 | | **Sensitivity to Initiation:** | |
| 5 | | Minimum Detonating Charge, gm | |
| 10 | | Mercury Fulminate | 0.23* |
| 15 | | Lead Azide | 0.22* |
| 20 | | Tetryl | |
| | | *Alternative initiating charges. | |
| **75°C International Heat Test:** | | **Ballistic Mortar, % TNT:** (a) | 132 |
| % Loss in 48 Hrs | | **Trauzl Test, % TNT:** | |
| **100°C Heat Test:** | | **Plate Dent Test:** (b) | |
| % Loss, 1st 48 Hrs | | Method | B |
| % Loss, 2nd 48 Hrs | | Condition | Cast |
| Explosion in 100 Hrs | | Confined | No |
| **Flammability Index:** | | Density, gm/cc | 1.68 |
| **Hygroscopicity:** % | | Brisance, % TNT | 127 |
| 30°C, 90% RH, 15 days | 0.00 | **Detonation Rate:** | |
| **Volatility:** | | Confinement | None |
| | | Condition | Cast |
| | | Charge Diameter, in. | 1.0 |
| | | Density, gm/cc | 1.64 |
| | | Rate, meters/second | 7655 |

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

| | |
|---|---|
| Density, gm/cc | 1.64 |
| Charge Wt, lb | 2.180 |
| **Total No. of Fragments:** | |
| For TNT | 703 |
| For Subject HE | 999 |

**3 inch HE, M42A1 Projectile, Lot KC-5:**

| | |
|---|---|
| Density, gm/cc | 1.63 |
| Charge Wt, lb | 0.864 |
| **Total No. of Fragments:** | |
| For TNT | 514 |
| For Subject HE | 685 |

**Fragment Velocity:** ft/sec

| | |
|---|---|
| At 9 ft | 2690 |
| At 25½ ft | 2460 |
| Density, gm/cc | 1.64 |

**Blast (Relative to TNT):**

| | |
|---|---|
| **Air:** | (d) |
| Peak Pressure | 111 |
| Impulse | 109 |
| Energy | -- |
| **Air, Confined:** | |
| Impulse | |
| **Under Water:** | |
| Peak Pressure | |
| Impulse | |
| Energy | |
| **Underground:** | |
| Peak Pressure | |
| Impulse | |
| Energy | |

Booster Sensitivity Test: (c)

| Condition | Pressed | Cast |
|---|---|---|
| Tetryl, gm | 100 | 100 |
| Wax, in. for 50% Detonation | 1.94 | 1.82 |
| Density, gm/cc | 1.61 | 1.68 |

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:**

**Principal Uses:** Land mines and demolition charges

**Method of Loading:** Cast

**Loading Density:** gm/cc 1.68

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | Exudes at 65°C |

Preparation:

The ternary explosive system consisting of RDX, tetryl and TNT is prepared by adding the appropriate weight of water-wet RDX to a tetrytol (40/60) previously melted in a steam-jacketed melt kettle. Heating and stirring are continued until all the water is evaporated and the mixture is uniform in composition. PTX-1 is also prepared by adding tetryl to RDX Composition B.

Compatibility with Metals:

Dry: Aluminum, mild steel not affected.

Wet: Aluminum, mild steel not affected.

PTX-1

Origin:

The possibility of employing ternary mixtures to obtain explosives having greater power and higher brisance than binary mixtures was suggested by the analysis of Russian 76 mm, armor piercing high explosive rounds (PATR No. 1311, 17 July 1943). The Russian type ternary explosives, based on the composition and laboratory studies of such mixtures, were indicated to be effective pressed fillers. In conducting a preliminary study of castable ternary explosive mixtures suggested by the Russian fillers, a mixture consisting of RDX/tetryl/TNT, designated PTX-1 was developed which had explosive and physical properties offering considerable advantage for military applications (PATR No. 1360, 27 October 1943; and 1379, 11 January 1944).

A PTX-3 composition, prepared by the addition of Haleite to 40/60 tetrytol, also offered promise but limited to applications where the charge would not be required to withstand storage at 65°C without exudation.

References:[65]

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(c) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

(d) W. R. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Tech Div Lecture, 9 April 1948.

(e) Also see the following Picatinny Arsenal Technical Reports on PTX-1:

| 0 | 2 | 3 | 6 | 7 | 9 |
|---|---|---|---|---|---|
| 1530 | 1402 | 1623 | 1466 | 1437 | 1379 |
| | | | 1506 | | 1429 |
| | | | | | 1469 |

[65]See footnote 1, page 10.

**Composition:**

| | % | |
|---|---|---|
| RDX | 44 | 41 |
| PETN | 28 | 26 |
| TNT | 28 | 33 |
| C/H Ratio | | |

**Impact Sensitivity, 2 Kg Wt:**
Bureau of Mines Apparatus, cm — 35
Sample Wt 20 mg
Picatinny Arsenal Apparatus, in.
Sample Wt, mg

**Friction Pendulum Test:**
Steel Shoe — Crackles
Fiber Shoe

**Rifle Bullet Impact Test:**

| | Trials | % |
|---|---|---|
| Explosions | | 60 |
| Partials | | 0 |
| Burned | | 0 |
| Unaffected | | 40 |

**Explosion Temperature:** °C
Seconds, 0.1 (no cap used)
1
5
10
15
20

**75°C International Heat Test:**
% Loss in 48 Hrs

**100°C Heat Test:**
% Loss, 1st 48 Hrs
% Loss, 2nd 48 Hrs
Explosion in 100 Hrs

**Flammability Index:**

**Hygroscopicity:** %
30°C, 90% RH, 15 days — 0.00

**Volatility:**

**Molecular Weight:** 244 — 243

**Oxygen Balance:**

| | | |
|---|---|---|
| $CO_2$ % | -33 | -36 |
| CO % | - 3 | - 4 |

**Density:** gm/cc — 1.70

**Melting Point:** °C — Eutectic — 75

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$
$n_{25}^{D}$
$n_{30}^{D}$

**Vacuum Stability Test:**
cc/40 Hrs, at
90°C
100°C — 2.6
120°C — 11+
135°C
150°C

**200 Gram Bomb Sand Test:**
Sand, gm — 56.9

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | 0.21 |
| Lead Azide | 0.00 |
| Tetryl | 0.00 |

**Ballistic Mortar, % TNT:** (a) — 138

**Trauzl Test, % TNT:**

**Plate Dent Test:** (b)

| | |
|---|---|
| Method | B |
| Condition | Cast |
| Confined | No |
| Density, gm/cc | 1.71 |
| Brisance, % TNT | 141 |

**Detonation Rate:**

| | |
|---|---|
| Confinement | None |
| Condition | Cast |
| Charge Diameter, in. | 1.0 |
| Density, gm/cc | 1.70 |
| Rate, meters/second | 8065 |

PTX-2

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

| | |
|---|---|
| Density, gm/cc | 1.68 |
| Charge Wt, lb | 2.226 |

**Total No. of Fragments:**

| | |
|---|---|
| For TNT | 703 |
| For Subject HE | 1128 |

**3 inch HE, M42A1 Projectile, Lot KC-5:**

| | |
|---|---|
| Density, gm/cc | 1.70 |
| Charge Wt, lb | 0.897 |

**Total No. of Fragments:**

| | |
|---|---|
| For TNT | 514 |
| For Subject HE | 750 |

**Fragment Velocity:** ft/sec

| | |
|---|---|
| At 9 ft | 3020 |
| At 25½ ft | 2850 |
| Density, gm/cc | 1.70 |

**Blast (Relative to TNT):**

| | |
|---|---|
| **Air:** | (a) |
| Peak Pressure | 113 |
| Impulse | 113 |
| Energy | -- |
| **Air, Confined:** | |
| Impulse | |
| **Under Water:** | |
| Peak Pressure | |
| Impulse | |
| Energy | |
| **Underground:** | |
| Peak Pressure | |
| Impulse | |
| Energy | |

Booster Sensitivity Test: (c)

| Condition | Pressed | Cast |
|---|---|---|
| Tetryl, gm | 100 | 100 |
| Wax, in. for 50% Detonation | 1.87 | 2.32 |
| Density, gm/cc | 1.70 | 1.61 |

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | ~130 | |
| Hole Depth | | |

**Color:**

**Principal Uses:** Shaped charges
Fragmentation charges

**Method of Loading:** Cast

**Loading Density:** gm/cc 1.70

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | None at 65°C |

Preparation:

The ternary explosive system consisting of RDX, PETN and TNT is prepared by adding the appropriate weight of water-wet RDX to a pentolite (30/70) previously melted in a steam-jacketed melt kettle. Heating and stirring are continued until all the water is evaporated and the mixture is uniform in composition. PTX-2 is also prepared by adding water-wet PETN to RDX Composition B.

Compatibility with Metals:

Dry: Aluminum, mild steel not affected.

Wet: Aluminum not affected.

Origin:

The possibility of employing ternary mixtures to obtain explosives having greater power and higher brisance than binary mixtures was suggested by the analysis of Russian 76 mm, armor-piercing high explosive rounds (PATR No. 1311, 17 July 1943). The Russian type ternary explosives, based on the composition and laboratory studies of such mixtures, were indicated to be effective pressed fillers. In conducting a preliminary study of castable ternary explosive mixtures suggested by the Russian fillers, a mixture consisting of RDX/PETN/TNT, designated PTX-2 was developed which had explosive and physical properties offering considerable advantage for military applications (PATR No. 1360, 27 October 1943; and 1379, 11 January 1944).

A PTX-4 composition, prepared by the addition of Haleite to 30/70 Pentolite, also offered promise but because of border-line stability in accelerated stability tests, PTX-4 must be proven by long term storage to be acceptable for use in standard ammunition.

References:[66]

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(c) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

(d) W. R. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Tech Div Lecture, 9 April 1948.

(e) Also see the following Picatinny Arsenal Technical Reports on PTX-2:

| 0 | 2 | 3 | 4 | 5 | 6 | 8 | 9 |
|---|---|---|---|---|---|---|---|
| 1530 | 1482 | 1483<br>1623 | 1414 | 1445 | 1466 | 1838 | 1379<br>1429<br>1469 |

[66] See footnote 1, page 10.

PVA-4

**Composition:**

| | % |
|---|---|
| RDX | 90 |
| Polyvinyl Acetate | 8 |
| Dibutylphthalate | 2 |
| C/H Ratio | |

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 39 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 9 |
| Sample Wt, mg | 13 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Crackles |
| Fiber Shoe | Unaffected |

**Rifle Bullet Impact Test:** 5 Trials *

| | % |
|---|---|
| Explosions | 20 |
| Partials | 0 |
| Burned | 60 |
| Unaffected | 20 |

*100 trials at -46°C - Unaffected

**Explosion Temperature:**

| Seconds, 0.1 (no cap used) | °C |
|---|---|
| 1 | 330 |
| 5 Decomposes | 375 |
| 10 | 265 |
| 15 | |
| 20 | |

**75°C International Heat Test:**
% Loss in 48 Hrs

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.10 |
| % Loss, 2nd 48 Hrs | 0.06 |
| Explosion in 100 Hrs | None |

**Flammability Index:**

**Hygroscopicity:** % 30°C, 90% RH 0.20

**Volatility:** 55°C, vacuo, 6 hrs 0.03

**Molecular Weight:** 217

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -37 |
| CO % | -10 |

**Density:** gm/cc Pressed 1.60

**Melting Point:** °C
Softening Point: °C 92

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$
$n_{25}^{D}$
$n_{30}^{D}$

**Vacuum Stability Test:**

| cc/40 Hrs, at | |
|---|---|
| 90°C | |
| 100°C | 0.45 |
| 120°C | 0.88 |
| 135°C | -- |
| 150°C | 11+ |

**200 Gram Bomb Sand Test:**

| | |
|---|---|
| Sand, gm | 58.5 |

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | |
| Lead Azide | 0.22 |
| Tetryl | |

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**Plate Dent Test:**

| | |
|---|---|
| Method | |
| Condition | |
| Confined | |
| Density, gm/cc | |
| Brisance, % TNT | |

**Detonation Rate:**

| | |
|---|---|
| Confinement | None |
| Condition | Cast |
| Charge Diameter, in. | 1.0 |
| Density, gm/cc | 1.60 |
| Rate, meters/second | 7910 |

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** White

**Principal Uses:** Demolition charges

**Method of Loading:** Pressed or extruded

**Loading Density:** gm/cc 1.60

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | None at 71°C |

Plasticity:

| | |
|---|---|
| -40°C | Cracked |
| 25°C | 0.3 |

PVA-4

Preparation:

Explosive PVA-4, a semi-plastic composition of Canadian origin, consists of 90% RDX, 8% polyvinyl acetate and 2% dibutylphthalate (DBP). This formulation was developed by Dr. Sutherland of Shawinigan Chemicals, Ltd. In evaluating various types of polyvinyl acetate commercially available in the United States, a type obtained from Union Carbide and Carbon, under the industrial named or designation "AYAT" was the most promising coating for RDX in the proportions RDX/PVA(AYAT)/DBP 92/6/2.

A practical method of preparing this composition was by the addition of a solution of the coating agent to an aqueous RDX slurry. Based on the quality of the product and the pellet densities obtained, a procedure of adding an acetone solution of PVA + DBP to a hot water slurry of RDX, under agitation, was adopted as standard.

References:[67]

(a) See the following Picatinny Arsenal Technical Reports on PVA-4: 1532 and 1634.

[67]See footnote 1, page 10.

**Composition:**

| | % |
|---|---|
| C | 27 |
| H | 3.4 |
| N | 15.6 |
| O | 54 |

$(H_2C\text{-}CH\text{-}ONO_2)_n$

C/H Ratio 0.203

**Impact Sensitivity, 2 Kg Wt:** 14.86%N

Bureau of Mines Apparatus, cm --

Sample Wt 20 mg

Picatinny Arsenal Apparatus, in. 4

Sample Wt, mg

**Friction Pendulum Test:**

Steel Shoe Crackles

Fiber Shoe Unaffected

**Rifle Bullet Impact Test:**

| | Trials | % |
|---|---|---|
| Explosions | | |
| Partials | | |
| Burned | | |
| Unaffected | | |

**Explosion Temperature:** °C

| Seconds, 0.1 (no cap used) | -- |
|---|---|
| 1 | -- |
| 5 | 265 |
| 10 | |
| 15 | |
| 20 | |

**75°C International Heat Test:**

% Loss in 48 Hrs

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 1.9 |
| % Loss, 2nd 48 Hrs | 2.1 |
| Explosion in 100 Hrs | None |

**Flammability Index:**

**Hygroscopicity:** % $30^{\circ}C$, 90% RH 0.62

**Volatility:**

**Molecular Weight:** $(C_2H_3NO_3)_n$ $(89)_n$

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -45 |
| CO % | - 9 |

**Density:** gm/cc

**Melting Point:** °C (Soft Pb) 50

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Vacuum Stability Test:**

| cc/40 Hrs, at | | |
|---|---|---|
| 90°C | | |
| 100°C | 16 hours | 11+ |
| 120°C | 16 hours | 11+ |
| 135°C | | |
| 150°C | | |

**200 Gram Bomb Sand Test:**

Sand, gm 49.9

**Sensitivity to Initiation:**

Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | -- |
| Lead Azide | |
| Tetryl | |

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**Plate Dent Test:**

Method

Condition

Confined

Density, gm/cc

Brisance, % TNT

**Detonation Rate:**

Confinement

Condition

Charge Diameter, in.

Density, gm/cc

Rate, meters/second

PVN (Polyvinyl Nitrate)

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**Fragment Velocity:** ft/sec

At 9 ft

At 25½ ft

Density, gm/cc

**Blast (Relative to TNT):**

**Air:**

Peak Pressure

Impulse

Energy

**Air, Confined:**

Impulse

**Under Water:**

Peak Pressure

Impulse

Energy

**Underground:**

Peak Pressure

Impulse

Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:**

**Principal Uses:**

**Method of Loading:**

**Loading Density:** gm/cc

**Storage:**

Method

Hazard Class (Quantity-Distance)

Compatibility Group

Exudation

65.5°C KI Test:

| | |
|---|---|
| Minutes | 60+ |

134.5°C Heat Test:

| | Minutes |
|---|---|
| Salmon Pink | 20 |
| Red Fumes | 25 |
| Explodes | 300+ |

240-Hour Hydrolysis Test:

| | |
|---|---|
| % $HNO_3$ | 5.07 |

Heat of:

| | |
|---|---|
| Combustion, cal/gm | 2960 |
| Explosion, cal/gm | 900 |
| Gas Volume, cc/gm | 838 |

Preparation:

Polyvinyl alcohol is mixed with acetic anhydride. The mixture is cooled to -5°C and the nitric acid is added slowly while the mass is being stirred. The temperature is controlled by the rate of acid addition so that when all the acid has been added the temperature does not rise above 20°C.

When the nitration is complete, the mixture is drowned by allowing a fine stream of the syrupy liquid to flow from the nitrator and mix intimately with a large stream of water. This causes the product to precipitate in a fine state.

The finely divided precipitate is purified by boiling in frequent changes of water.

Origin:

The first preparation of polyvinyl nitrate was reported in 1929 by solution of polyvinyl alcohol in concentrated sulfuric acid and treatment with nitrating acid at a temperature not over 50°C. (German Patent 537,303). Later patents issued relative to polyvinyl nitrate included U. S. Patent 2,118,487 (1938) and German Patent 737,199 (1943).

**Composition:**
%

| | |
|---|---|
| RDX | 85 |
| Gulf Crown E Oil | 15 |

C/H Ratio

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 53 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 13 |
| Sample Wt, mg | 25 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | Unaffected |

**Rifle Bullet Impact Test:**

| | Trials | % |
|---|---|---|
| Explosions | | 0 |
| Partials | | 0 |
| Burned | | 0 |
| Unaffected | | 100 |

**Explosion Temperature:** °C
Seconds, 0.1 (no cap used)
1
5 Decomposes; no value obtained
10
15
20

**75°C International Heat Test:**
% Loss in 48 Hrs

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.03 |
| % Loss, 2nd 48 Hrs | 0.04 |
| Explosion in 100 Hrs | None |

**Flammability Index:**

**Hygroscopicity:** % 30°C, 90% RH 0.04

**Volatility:**

**Molecular Weight:** 230

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -70 |
| CO % | -35 |

**Density:** gm/cc Hand tamped 1.37

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$
$n_{25}^{D}$
$n_{30}^{D}$

**Vacuum Stability Test:**
cc/40 Hrs, at

| | |
|---|---|
| 90°C | -- |
| 100°C | 0.34 |
| 120°C | 0.56 |
| 135°C | |
| 150°C | |

**200 Gram Bomb Sand Test:**

| | |
|---|---|
| Sand, gm | 40.1 |

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | |
| Lead Azide | 0.20 |
| Tetryl | |

**Ballistic Mortar, % TNT:** (a) 118

**Trauzl Test, % TNT:**

**Plate Dent Test:** (b)

| | |
|---|---|
| Method | B |
| Condition | Hand tamped |
| Confined | No |
| Density, gm/cc | 1.37 |
| Brisance, % TNT | 85 |

**Detonation Rate:**

| | |
|---|---|
| Confinement | None |
| Condition | Hand tamped |
| Charge Diameter, in. | 1.0 |
| Density, gm/cc | 1.37 |
| Rate, meters/second | 7390 |

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

| | |
|---|---|
| Density, gm/cc | 1.36 |
| Charge Wt, lb | 1.766 |
| **Total No. of Fragments:** | |
| For TNT | 703 |
| For Subject HE | 592 |

**3 inch HE, M42A1 Projectile, Lot KC-5:**

| | |
|---|---|
| Density, gm/cc | 1.42 |
| Charge Wt, lb | 0.756 |
| **Total No. of Fragments:** | |
| For TNT | 514 |
| For Subject HE | 501 |

**Fragment Velocity:** ft/sec

| | |
|---|---|
| At 9 ft | 2650 |
| At 25½ ft | 2370 |
| Density, gm/cc | 1.395 |

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

Preparation:

RIPE is manufactured by simple mechanical mixing of RDX in oil.

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** White

**Principal Uses:** Plastic demolition explosive

**Method of Loading:** Hand tamped

**Loading Density:** gm/cc 1.37

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | None at 85°C in 30 hrs<br>None at 95°C in 48 hrs<br>Exudes at 105°C in 48 hrs |

Origin:

RIPE, a mechanical mixture of RDX and Gulf Crown E Oil, was developed in the United States during World War II.

References:[68]

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(c) Also see the following Picatinny Arsenal Technical Reports on RIPE: 1713, 1695 and 1517.

[68]See footnote 1, page 10.

# Silver Azide

**Composition:**
%
N 28.0
Ag 72.0
$Ag-N=N\equiv N$

C/H Ratio

**Molecular Weight:** ($AgN_3$) 150

**Oxygen Balance:**
$CO_2$ % -5
CO % -5

**Density:** gm/cc Crystal 5.1

**Melting Point:** °C (a) 251
Decomposes rapidly above melting point to silver and nitrogen.

**Freezing Point:** °C

**Boiling Point:** °C

**Impact Sensitivity, 2 Kg Wt:**
Bureau of Mines Apparatus, cm 6
Sample Wt 20 mg
Picatinny Arsenal Apparatus, in. 3
Sample Wt, mg 18

**Refractive Index,** $n_{20}^{D}$
$n_{25}^{D}$
$n_{30}^{D}$

**Friction Pendulum Test:** PA Small Apparatus
Steel Shoe Detonates
Fiber Shoe Detonates

**Vacuum Stability Test:**
cc/40 Hrs, at
90°C
100°C
120°C
135°C
150°C

**Rifle Bullet Impact Test:** Trials
%
Explosions
Partials
Burned
Unaffected

**200 Gram Bomb Sand Test:**
Sand, gm (b)
Black powder fuse 18.9

**Explosion Temperature:** °C
Seconds, 0.1 (no cap used) 310
1 --
5 Explodes 290
10
15
20

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm
Mercury Fulminate
Lead Azide
Tetryl

**Ballistic Mortar, % TNT:**

**Trauzl Test, %** $Hg(ONC)_2$ (c) 88

**75°C International Heat Test:**
% Loss in 48 Hrs

**Plate Dent Test:**
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**100°C Heat Test:**
% Loss, 1st 48 Hrs
% Loss, 2nd 48 Hrs
Explosion in 100 Hrs

**Detonation Rate:**
Confinement
Condition
Charge Diameter, in.
Density, gm/cc
Rate, meters/second

**Flammability Index:**

**Hygroscopicity:** % (b) 25°C, 100% RH 0.04

**Volatility:** 75°C, 24 hrs 0.00

# Silver Azide

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

Explosive Power: (f)

| | |
|---|---|
| Kilogram meters | 192,000 |
| % Mercury Fulminate | 1.097 |

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** White to gray

**Principal Uses:** Initiators

**Method of Loading:** Pressed

**Loading Density:** gm/cc Variable

**Storage:**

| | |
|---|---|
| Method | Wet |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group M |
| Exudation | None |

Initiating Efficiency:

| | |
|---|---|
| Grams Required to Give Complete Initiation of TNT | (c) 0.02-0.05 |

Solubility in 100 gm Solvent at Room Temperature:

| Solvent | Grams |
|---|---|
| Water (b) | 0.006 |
| Ammonium hydroxide | Soluble |
| Nitric acid | Decomposes |
| Ether (b) | 0.017 |
| Ethyl alcohol, 95% | 0.006 |
| Acetone | 0.015 |

Unaffected by water and $CO_2$. (d)

Heat of:

| | |
|---|---|
| Explosion, cal/gm (c, d) | 452 |
| Formation, cal/gm (e) | 67.8 |

# Silver Azide

Preparation:

$$NaN_3 + AgNO_3 \longrightarrow AgN_3 \downarrow + NaNO_3$$

Prepare the following aqueous solutions:

a. 5% $NaN_3$, sodium azide, 50 cc

b. 25% $AgNO_3$, silver nitrate, 25 cc

The silver nitrate solution is placed in a 200 cc conductive rubber beaker equipped with a hard wood stirrer operated by an air motor. The sodium azide solution is placed in a separatory funnel fastened in a ring stand above the beaker containing the silver nitrate. A long cord (10 ft) is fastened to the stopcock of the separatory funnel so that the funnel can be emptied by remote control. The silver nitrate solution is now stirred very rapidly and the sodium azide is slowly run into the nitrate solution. Stirring is continued for 5 minutes. The contents of the beaker are filtered through folded filter paper and washed free of sodium azide and silver nitrate with distilled water.

Silver azide should be stored under water in a conductive rubber container. This preparation will yield approximately 7 grams.

The preparation should be conducted under a hood and behind a barricade. The product obtained by the above procedure has a very fine particle size, almost colloidal. Very fine silver azide is safer to handle and is just as efficient and stable as the large, coarse crystalline material (Ref b). When a thin film of fine silver azide is precipitated on mercury fulminate, tetryl, etc., these substances are as efficient weight for weight as pure silver azide (Ref g). White silver azide is less affected by light than mercury or lead azide (Ref h). Long colorless crystals which explode on breaking are obtained from ammonium hydroxide.

Origin:

Silver azide was first prepared in 1890-1 by T. Curtius (Ber 23, 3032; Ber 24, 3344-5) by passing hydrazoic acid ($HN_3$) into neutral silver nitrate solution. Taylor and Rinkenbach prepared pure "collodial" aggregates and showed its sensitivity depends upon its particle size (Army Ordnance 5, 824 (1925). Silver azide was found in a detonator of foreign ammunition for the first time in 1945 (Ref i).

References:[69]

(a) A. R. Hitch, "Thermal Decomposition of Certain Inorganic Trinitrides," J Am Chem Soc 40, 1195 (1918).

(b) C. A. Taylor and Wm. H. Rinkenbach, "Silver Azide: An Initiator of Detonation," Army Ordnance, Vol 5, p. 824 (1925).

(c) E. De W. S. Colver, High Explosives, London and New York, p. 527.

(d) A. Stettbacher, Spreng u. Schiesstoffe, Rascher, Zurich, p. 97 (1948).

(e) A. Marshall, Explosives, 2nd Ed, Vol II, p. 767, London.

(f) A. Stettbacher, Z ges Schiess-Sprengstoffw 10, pp. 193-214 (1915).

[69]See footnote 1, page 10.

(g) F. Blechta, Chim et Ind Special No. 921-5 (June 1933); C. A. 28, 646.

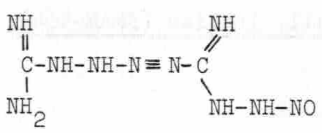
(h) L. Wohler and W. Krupko, Berichte 46, 2047-2050 (1913).

(i) F. G. Haverlak, Examination of 120/45 MM HE Shell, Italian (FMAM-464), PATR No. 1515, 10 April 1945.

# Tetracene

**Composition:**

| | % |
|---|---|
| C | 12.8 |
| H | 4.3 |
| N | 74.4 |
| O | 8.5 |



C/H Ratio 0.068

**Molecular Weight:** ($C_2H_8N_{10}O$) 188

**Oxygen Balance:**
- $CO_2$ % -60
- CO % -43

**Density:** gm/cc At 3000 psi 1.05

**Melting Point:** °C Explodes 140-160

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ / $n_{25}^{D}$ / $n_{30}^{D}$

**Impact Sensitivity, 2 Kg Wt:**
- Bureau of Mines Apparatus, cm 7
  Sample Wt 20 mg
- Picatinny Arsenal Apparatus, in.2; (8 oz wt) 8
  Sample Wt, mg

**Friction Pendulum Test:**
- Steel Shoe
- Fiber Shoe

**Vacuum Stability Test:**
cc/40 Hrs, at
- 90°C
- 100°C
- 120°C
- 135°C
- 150°C

**Rifle Bullet Impact Test:**

| | Trials | % |
|---|---|---|
| Explosions | | |
| Partials | | |
| Burned | | |
| Unaffected | | |

**200 Gram Bomb Sand Test:**
- Sand, gm 28.0
- Black powder fuse 4.0

**Explosion Temperature:** °C
Seconds, 0.1 (no cap used)
- 1
- 5 160
- 10
- 15
- 20

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm
- Mercury Fulminate 0.40
- Lead Azide
- Tetryl

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:** (a) 61

**75°C International Heat Test:**
- % Loss in 48 Hrs 0.5

**Plate Dent Test:**
- Method
- Condition
- Confined
- Density, gm/cc
- Brisance, % TNT

**100°C Heat Test:**
- % Loss, 1st 48 Hrs 23.2
- % Loss, 2nd 48 Hrs 3.4
- Explosion in 100 Hrs None

**Detonation Rate:**
- Confinement
- Condition
- Charge Diameter, in.
- Density, gm/cc
- Rate, meters/second

**Flammability Index:**

**Hygroscopicity:** % 30°C, 90% RH 0.77

**Volatility:**

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**Fragment Velocity:** ft/sec

At 9 ft

At 25½ ft

Density, gm/cc

**Blast (Relative to TNT):**

**Air:**

Peak Pressure

Impulse

Energy

**Air, Confined:**

Impulse

**Under Water:**

Peak Pressure

Impulse

Energy

**Underground:**

Peak Pressure

Impulse

Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Pale yellow

**Principal Uses:** Priming compositions and detonators

**Method of Loading:** Pressed

**Loading Density:** gm/cc

At 3000 psi 1.05

**Storage:**

| | |
|---|---|
| Method | Wet |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group M |
| Exudation | |

Solubility:

Practically insoluble in water, alcohol, acetone, ether, benzene, carbontetrachloride or ethylenedichloride.

| Sensitivity to Electrostatic Discharge, Joules: | (b) |
|---|---|
| Unconfined | 0.010 |
| Confined | 0.012 |

Heat of:

| | |
|---|---|
| Explosion, cal/gm | 658 |
| Gas Volume, cc/gm | 1190 |

Initiating Efficiency:

Tetracene is not efficient in initiating high explosives.

# Tetracene

Preparation:

(Rinkenbach and Burton, Army Ordnance 12, 120 (1931)).

Tetracene is prepared by dissolving 5 gms of aminoguanidine dinitrate in 30 cc of water, cooling to 0°C and mixing with a solution of 2.5 gms of sodium nitrate in 15 cc of water. The temperature is maintained at about 10°C and 0.5 gm of acetic acid is added. The tetracene separates out and is washed with water, alcohol and ether. It is then dried.

Tetracene may also be prepared by placing aminoguanidine sulphate and sodium nitrite in a large beaker and adding water heated to 30°C. The heat of reaction causes the mixture to boil; after standing for two or three hours the separated tetracene is filtered off, washed thoroughly and dried.

Origin:

Tetracene was first prepared in 1910 by Hoffman and Roth (Ber 43, 682) who also studied its chemical reactions and determined its structure (Hoffman et al, Ber 43, 1087, 1866 (1910); Ber 44, 2496 (1911); and Ann 380, 131 (1911)). W. H. Rinkenbach and O. Burton made an extensive study of tetracene and described its manufacture and explosive properties (Army Ordnance 12, 120 (1931)).

Destruction by Chemical Decomposition:

Tetracene is decomposed by adding it to boiling water and continuing boiling for some time to insure complete decomposition.

References:[70]

(a) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) F. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.

(c) Also see the following Picatinny Arsenal Technical Reports on Tetracene:

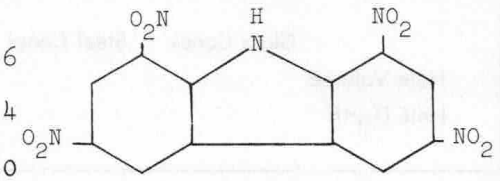
| 0 | 1 | 3 | 4 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|
| 1450 | 11 | 453 | 1104<br>2164 | 407 | 318 | 859<br>2179 |

[70] See footnote 1, page 10.

**Composition:**

| | % |
|---|---|
| C | 41.6 |
| H | 1.4 |
| N | 20.0 |
| O | 37.0 |

C/H Ratio 1.032




**Molecular Weight:** $(C_{12}H_5N_5O_8)$ 347

**Oxygen Balance:**
- $CO_2$ % -85
- CO % -30

**Density:** gm/cc

**Melting Point:** °C Pure 1,3,6,8-isomer 296

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^D$ / $n_{25}^D$ / $n_{30}^D$

**Impact Sensitivity, 2 Kg Wt:**
- Bureau of Mines Apparatus, cm 100+
  Sample Wt 20 mg
- Picatinny Arsenal Apparatus, in. 18
  Sample Wt, mg 14

**Friction Pendulum Test:**
- Steel Shoe Unaffected
- Fiber Shoe Unaffected

**Vacuum Stability Test:**
cc/40 Hrs, at
- 90°C
- 100°C 0.2
- 120°C 0.2
- 135°C
- 150°C

**Rifle Bullet Impact Test:**

| | Trials | % |
|---|---|---|
| Explosions | | |
| Partials | | |
| Burned | | |
| Unaffected | | |

**200 Gram Bomb Sand Test:**
- Sand, gm 41.3

**Explosion Temperature:** °C
- Seconds, 0.1 (no cap used) --
- 1 --
- 5 Decomposes 470
- 10
- 15
- 20

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm
- Mercury Fulminate --
- Lead Azide 0.20
- Tetryl 0.25

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**75°C International Heat Test:**
- % Loss in 48 Hrs

**Plate Dent Test:**
- Method
- Condition
- Confined
- Density, gm/cc
- Brisance, % TNT

**100°C Heat Test:**
- % Loss, 1st 48 Hrs 0.15
- % Loss, 2nd 48 Hrs 0.05
- Explosion in 100 Hrs None

**Detonation Rate:**
- Confinement
- Condition
- Charge Diameter, in.
- Density, gm/cc
- Rate, meters/second

**Flammability Index:**

**Hygroscopicity:** % 30°C, 90% RH 0.01

**Volatility:**

# Tetranitrocarbazole (TNC)

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Light yellow

**Principal Uses:** Component of igniter and pyrotechnic compositions

**Method of Loading:** Pressed

**Loading Density:** gm/cc

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | |
| Exudation | |

Solubility in Water, gm/100 gm (%), at:

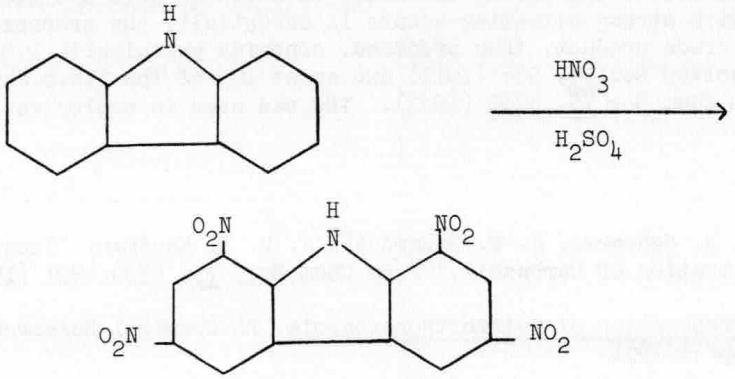
| | |
|---|---|
| 95°C | 0.10 |

Qualitative Solubilities:

| Solvent | Solubility |
|---|---|
| Nitrobenzene | Very soluble |
| Acetone | Soluble |
| Benzene | Insoluble |
| Chloroform | Insoluble |
| Carbontetrachloride | Insoluble |
| Ether | Insoluble |
| Ether, petroleum | Insoluble |

## Tetranitrocarbazole (TNC)

Preparation:




Sulfonation: Fifty-six gms of carbazole is dissolved in 320 gms of $H_2SO_4$ (96%, specific gravity 1.84). The solution is agitated during the addition of the carbazole and the temperature maintained at 25°-35°C. After the addition of the carbazole is completed, the agitation is continued and solution completed by raising the temperature to 80°-85°C and maintaining this temperature for one hour. The sulphate is now cooled to 20°C.

Nitration: The sulfonate solution is slowly added to 168 gms of $HNO_3$ (Plant grade specific gravity 1.525 at 15°C) maintaining the temperature at 30° to 50°C. (Time required - 1 hour 25 minutes). The temperature is then gradually raised to 70° to 75°C and maintained for one hour after which the temperature is raised to 85° to 90°C and held for one hour, then lowered to room temperature before drowning.

Drowning: The nitration mixture is drowned by pouring it into 2 to 3 volumes of ice and water.

Filtering: The separated light yellow product is filtered on a Buchner Funnel and washed with water twice to remove most of the acid.

Purification: The TNC is placed in hot water (95° to 100°C) and boiled for five to ten minutes with rapid agitation, allowed to settle then filtered and washed once. This procedure is repeated twice, making a total of three "boilings." The final wash is acid free.

Drying: The TNC is spread in a thin layer and dried at 100° to 110°C for four hours.

Yield: 73.3%.

Melting Point of TNC as prepared: 280°C (compares to 296°C for pure 1,3,6,8-isomer in preceding data).

Origin:

The preparation of Tetranitrocarbazole (TNC) was first reported in 1880 by C. Graebe (Ann 202, 26 (1880)) who nitrated carbazole with 94% nitric acid. Similar procedures were followed by R. Escales (Ber 37, 3596 (1904)) and P. Zierch (Ber 42, 3800 1909)). However, G. L. Ciamician and P. P. Silber observed the formation of four isomeric TNC's when acetyl carbazole was treated with fuming nitric acid (Gazz chim ital 12, 272 1882)). In 1912 and 1913 patents were issued to the dyestuff manufacturer, Casella and Company, covering the preparation of polynitrocarbazoles (German Patent 268,173 and French Patent 464,538). The Casella process of

preparing polynitrocarbazoles by dissolving carbazole in sulfuric acid and treating the solution of sulfonic acids with strong nitrating agents is essentially the process used today in the United States. The crude product, thus prepared, contains principally 1,3,6,8-TNC (W. Borsche and B. G. B. Scholten Ber 50, 596 (1917) and about 10% of the 1,2,6,8-TNC isomer (D. B. Murphy et al J Am Chem Soc 75, 4289 (1953). TNC was used in explosives by the Germans during World War II.

References:[71]

(a) D. B. Murphy, F. R. Schwartz, J. P. Picard and J. V. R. Kaufman, "Identification of Isomers Formed in the Nitration of Carbazole," J Am Chem Soc, 75, 4289-4291 (1953).

(b) S. Livingston, Preparation of Tetranitrocarbazole, PA Chemical Research Laboratory Report No. 136,330, 11 April 1951.

(c) D. B. Murphy et al, Long Range Basic Technical Research Leading to the Development of Improved Ignition Type Powders - The Chemistry of Tetranitrocarbazole, PA Memorandum Report No. 22, 2 September 1952.

(d) S. Livingston, Development of Improved Ignition Type Powders, PATR No. 2267, July 1956.

(e) Also see the following Picatinny Arsenal Technical Reports on Tetranitrocarbazole:

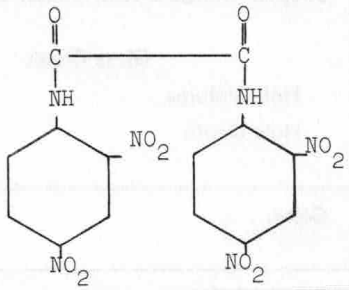
| 0 | 2 | 3 | 4 | 7 |
|---|---|---|---|---|
| 2180 | 1802 | 1973 | 1984 | 1647<br>1937 |

[71]See footnote 1, page 10.

# 2,4,2',4'-Tetranitro-oxanilide (TNO)

**Composition:**

| | % |
|---|---|
| C | 40.0 |
| H | 1.9 |
| N | 20.0 |
| O | 38.1 |
| C/H Ratio | 0.735 |



**Molecular Weight:** ($C_{14}H_8N_6O_{10}$) 420

**Oxygen Balance:**
- $CO_2$ % -84
- CO % -31

**Density:** gm/cc

**Melting Point:** °C Decomposes 313

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^D$ / $n_{25}^D$ / $n_{30}^D$

**Impact Sensitivity, 2 Kg Wt:**
- Bureau of Mines Apparatus, cm --
- Sample Wt 20 mg
- Picatinny Arsenal Apparatus, in. 30
- Sample Wt, mg 11

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | Unaffected |

**Vacuum Stability Test:**
cc/40 Hrs, at

| | |
|---|---|
| 90°C | -- |
| 100°C | -- |
| 120°C | 0.11 |
| 135°C | |
| 150°C | |

**Rifle Bullet Impact Test:** Trials / %
- Explosions
- Partials
- Burned
- Unaffected

**200 Gram Bomb Sand Test:**
- Sand, gm 16.3

**Explosion Temperature:** °C

| Seconds, 0.1 (no cap used) | -- |
|---|---|
| 1 | -- |
| 5 | 392 |
| 10 | |
| 15 | |
| 20 | |

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm
- Mercury Fulminate
- Lead Azide 0.20
- Tetryl 0.25

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**75°C International Heat Test:**
- % Loss in 48 Hrs

**Plate Dent Test:**
- Method
- Condition
- Confined
- Density, gm/cc
- Brisance, % TNT

**100°C Heat Test:**
- % Loss, 1st 48 Hrs 0.07
- % Loss, 2nd 48 Hrs 0.00
- Explosion in 100 Hrs None

**Detonation Rate:**
- Confinement
- Condition
- Charge Diameter, in.
- Density, gm/cc
- Rate, meters/second

**Flammability Index:**

**Hygroscopicity:** % 30°C, 90% RH Trace

**Volatility:**

## 2,4,2',4'-Tetranitro-oxanilide (TNO)

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Light yellow

**Principal Uses:** Component of black powder type and pyrotechnic compositions

**Method of Loading:** Pressed and extruded compositions

**Loading Density:** gm/cc

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | |
| Exudation | |

Solubility, gm/100 cc Solvent, in:

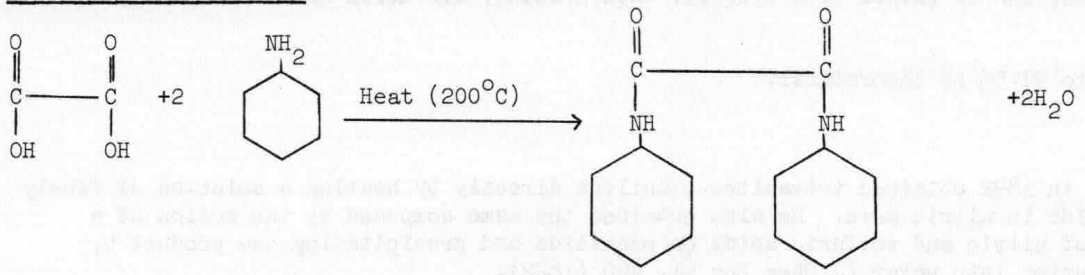
| | °C | % |
|---|---|---|
| Water | 100 | <0.10 |
| Nitrobenzene | 150 | >15 |

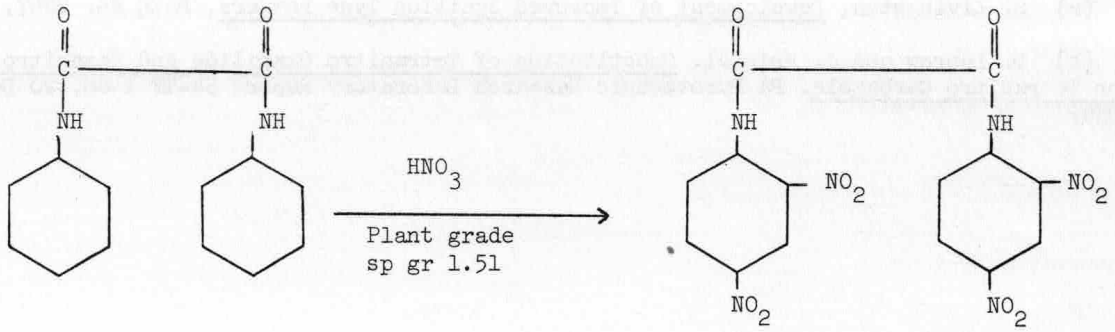
Qualitative Solubilities:

| Solvent | Solubility |
|---|---|
| Ethyl alcohol | Insoluble |
| Benzene | Insoluble |
| Butyl acetate | Insoluble |
| Carbontetrachloride | Insoluble |
| Ethyl ether | Insoluble |
| Acetic acid | Soluble |
| Nitric acid | Soluble |
| Caustic potash | Soluble |
| Dimethyl formamide | Very soluble |

## 2,4,2',4'-Tetranitro-oxanilide (TNO)

Method of Preparation:




Oxanilide:

Two parts of oxalic acid are mixed with one part of aniline in a round bottom flask. The mixture is stirred and heated until the reaction is complete as evidenced by the cessation of effervescence. The mass is cooled to room temperature, poured into several volumes of water (21°-24°C), filtered on a Büchner funnel and washed free of oxalic acid with water and then washed free of aniline with acetone. The oxanilide is air dried to remove the acetone and then dried at 100°-110°C.

Tetranitro-oxanilide (TNO):

A 5 liter round bottom flask is equipped with a stirrer of a type which will produce a downward "swirl." The flask is surrounded with a water jacket for hot and cold water. Fifteen hundred grams (1.5 kilograms) of 98% plant grade nitric acid is placed into the flask. Five hundred (500) grams of oxanilide is slowly added to the acid under rapid agitation while the temperature is maintained below 40°C. After the addition of the oxanilide is completed (2½-3 hrs), the agitation is continued 10-15 minutes. The temperature is then raised to 80°C over a period of one hour and maintained at 80°-85°C for 3 hours. The acid slurry is then cooled to room temperature and drowned by pouring over cracked ice. The product is filtered on a Büchner funnel and washed with water until it is almost acid free. The filter cake is placed in a beaker and sufficient water added to form a "slurry." Live steam is run into the "slurry" under agitation for 10 minutes. The slurry is filtered and the residue washed. The latter treatment of the "slurry" is repeated until the wash water is found to be neutral to

litmus paper. The TNO is washed with alcohol, then acetone, air dried and finally dried at 100°-110°C.

Yield = 90% to 97.5% of theoretical.

Origin:

A. G. Perkin in 1892 obtained tetranitro-oxanilide directly by heating a solution of finely powdered oxanilide in nitric acid. He also obtained the same compound by the action of a cooled mixture of nitric and sulfuric acids on oxanilide and precipitating the product by pouring the solution into water (J Chem Soc 61, 460 (1892).

References:[72]

(a) S. Livingston, Development of Improved Ignition Type Powders, PATR No. 2267, July 1956.

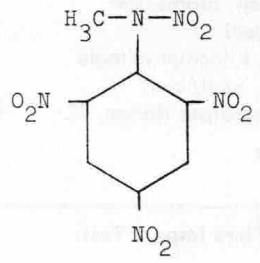
(b) D. Dubrow and J. Kristal, Substitution of Tetranitro Oxanilide and Hexanitro Oxanilide for Tetranitro Carbazole, PA Pyrotechnic Research Laboratory Report 54-TF 1-88, 20 December 1954.

[72]See footnote 1, page 10.

**Composition:**

| | % |
|---|---|
| C | 29.3 |
| H | 1.7 |
| N | 24.4 |
| O | 44.6 |

C/H Ratio 0.420




**Molecular Weight:** $(C_7H_5N_5O_8)$ 287

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -47 |
| CO % | - 8 |

**Density:** gm/cc Crystal 1.73

**Melting Point:** °C 130

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 26 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 8 |
| Sample Wt, mg | 18 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Crackles |
| Fiber Shoe | Unaffected |

**Vacuum Stability Test:**

cc/40 Hrs, at

| | |
|---|---|
| 90°C | -- |
| 100°C | 0.3 |
| 120°C | 1.0 |
| 135°C | -- |
| 150°C | 11+ |

**Rifle Bullet Impact Test:**

| | Trials % |
|---|---|
| Explosions | 13 |
| Partials | 54 |
| Burned | 10 |
| Unaffected | 23 |

**200 Gram Bomb Sand Test:**

Sand, gm 54.2

**Explosion Temperature:**

| Seconds, 0.1 (no cap used) | °C 340 |
|---|---|
| 1 | 314 |
| 5 Ignites | 257 |
| 10 | 238 |
| 15 | 236 |
| 20 | 234 |

**Sensitivity to Initiation:**

Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | 0.20* |
| Lead Azide | 0.10* |
| Tetryl | |

*Alternative initiating charges.

**Ballistic Mortar, % TNT:** (a) 130

**75°C International Heat Test:**

% Loss in 48 Hrs 0.01

**Trauzl Test, % TNT:** (b) 125

**Plate Dent Test:** (c)

| | | | |
|---|---|---|---|
| Method | A | | B |
| Condition | Pressed | | Pressed |
| Confined | Yes | | No |
| Density, gm/cc | 1.50 | 1.59 | 1.36 |
| Brisance, % TNT | 116 | 115 | 96 |

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.1 |
| % Loss, 2nd 48 Hrs | 0.0 |
| Explosion in 100 Hrs | None |

**Flammability Index:** 244

**Hygroscopicity:** % 30°C, 90% RH 0.04

**Volatility:** 25°C 0.00

**Detonation Rate:**

| | |
|---|---|
| Confinement | None |
| Condition | Pressed |
| Charge Diameter, in. | 1.0 |
| Density, gm/cc | 1.71 |
| Rate, meters/second | 7850 |

**Booster Sensitivity Test:** (d)

| | |
|---|---|
| Condition | Pressed |
| Tetryl, gm | 100 |
| Wax, in. for 50% Detonation | 2.01 |
| Wax, gm | |
| Density, gm/cc | 1.58 |

**Heat of:**

| | |
|---|---|
| Combustion, cal/gm | 2925 |
| Explosion, cal/gm | 1080-1130 |
| Gas Volume, cc/gm | 760 |
| Formation, cal/gm | -14 |
| Fusion, cal/gm (e) | 22.2 |
| Temperature, °C | 127 |

**Specific Heat:** cal/gm/°C (e)

| °C | |
|---|---|
| -100 | 0.182 |
| - 50 | 0.200 |
| 0 | 0.212 |
| 50 | 0.223 |
| 100 | 0.236 |

**Burning Rate:**
cm/sec

**Thermal Conductivity:** (f)
cal/sec/cm/°C $5.81 \times 10^{-4}$ at 1.394 gm/cc
$6.83 \times 10^{-4}$ at 1.528 gm/cc

**Coefficient of Expansion:**
Linear, %/°C

Volume, %/°C

**Hardness, Mohs' Scale:**

**Young's Modulus:**
E', dynes/cm²
E, lb/inch²
Density, gm/cc

**Compressive Strength:** lb/inch²

**Vapor Pressure:**
°C mm Mercury

**Decomposition Equation:** (g) (h)

| | | |
|---|---|---|
| Oxygen, atoms/sec (Z/sec) | $10^{15.4}$ | $10^{12.9}$ |
| Heat, kilocalorie/mole (ΔH, kcal/mol) | 38.4 | 34.9 |
| Temperature Range, °C | 211-260 | 132-164 |
| Phase | Liquid | Liquid |

**Armor Plate Impact Test:**

**60 mm Mortar Projectile:**
50% Inert, Velocity, ft/sec
Aluminum Fineness

**500-lb General Purpose Bombs:**

Plate Thickness, inches

1
1¼
1½
1¾

**Bomb Drop Test:**

**T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:**

Max Safe Drop, ft

**500-lb General Purpose Bomb vs Concrete:**

Height, ft
Trials
Unaffected
Low Order
High Order

**1000-lb General Purpose Bomb vs Concrete:**

Height, ft
Trials
Unaffected
Low Order
High Order

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

| | |
|---|---|
| Density, gm/cc | 1.58 |
| Charge Wt, lb | 2.052 |

**Total No. of Fragments:**

| | |
|---|---|
| For TNT | 703 |
| For Subject HE | 864 |

**3 inch HE, M42A1 Projectile, Lot KC-5:**

| | |
|---|---|
| Density, gm/cc | 1.62 |
| Charge Wt, lb | 0.848 |

**Total No. of Fragments:**

| | |
|---|---|
| For TNT | 514 |
| For Subject HE | 605 |

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Light yellow

**Principal Uses:** Boosters; ingredient of explosive mixtures, detonators, and blasting caps

**Method of Loading:** Pressed

**Loading Density:** gm/cc See below

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group L |
| Exudation | Does not exude at 65°C |

Loading Density: gm/cc

Cast 1.62 Pressed psi x $10^3$

| 0 | 3 | 5 | 10 | 12 | 15 | 20 |
|---|---|---|---|---|---|---|
| 0.9 | 1.40 | 1.47 | 1.57 | 1.60 | 1.63 | 1.67 |

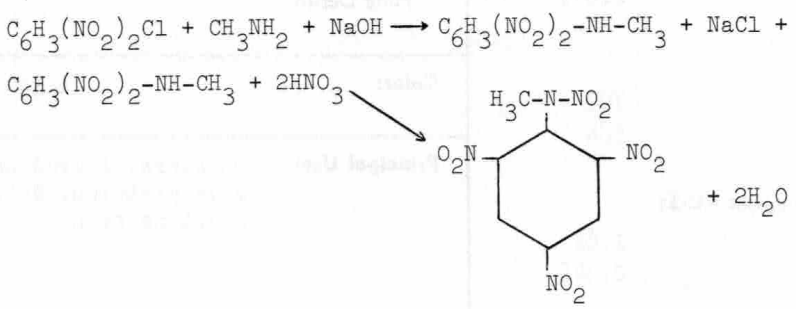
30
1.71

Effect of Temperature on Rate of Detonation: (j)

| 16 hrs at, °C | -54 | 21 |
|---|---|---|
| Density, gm/cc | 1.52 | 1.53 |
| Rate, m/sec | 7150 | 7170 |

Preparation:

(Manufacture of Tetryl by Dinitromonomethylaniline Process, Wannamaker Chemical Co., Inc.)



To a solution of 202.5 gm dinitrochlorbenzene in 200 cc benzene, at 75°C with good agitation, in 15 to 20 minutes, add 112 gm of 30% aqueous monomethylamine. Then add 129 gm of 31% aqueous sodium hydroxide, in 15 to 20 minutes, at such a rate as to cause refluxing; continue agitation for 3 hours at 70°C. The mixture is concentrated to a liquid temperature of 101°-102°C, cooled, filtered and the precipitate washed with distilled water until the washings give no test with silver nitrate, dried at 60°C (melting point 167.2°C).

The dinitromethylaniline is nitrated to tetryl by solution of it in 88% sulfuric acid (197 gm nitroaniline/1190 gm sulfuric) at 25°C, followed by addition of nitric acid. The process is carried out so that the water content remains at 16%. Solution (per 197 gm nitroaniline) requires 5 to 10 minutes, nitration, by addition of the sulfuric acid solution to nitric acid, about 1 hour at 30°C, plus 48 minutes at 50° to 55°C at the end. The mixture is then cooled to 20°C and filtered. The tetryl is dumped into 1 liter water, washed 2 or 3 times with 200 cc cold water, and then stirred 10 to 15 minutes at 50°C with 500 cc water, filtered warm and then washed with water until the washings are neutral to methyl orange. The tetryl dried to constant weight at 70°C weighs about 270 gm.

Tetryl filtered from an acid containing 87% sulfuric acid (or more) -13% water, at 40°C (or over) may fire in 30 minutes to 1 hour and 30 minutes, if not drowned in water. A safe nitration procedure, even on plant scale involves:

1. The concentration of sulfuric in the spent acid is maintained at a low level (approx 80/1.8/18.2 sulfuric/nitric/water).

2. Nitration maximum temperature is 50°C.

3. The slurry is cooled to 35°C before filtration.

4. Filtration time prior to drowning, is minimized (15 minutes maximum).

The crude tetryl produced is recrystallized to remove impurities and occluded acid and to control its granulation.

# Tetryl

Sensitivity of tetryl electrostatic discharge, joules; through 100 mesh: (i)

| | |
|---|---|
| Unconfined | 0.007 |
| Confined | 4.4 |

Solubility of tetryl, grams in 100 grams (%) of:

| Water | | Carbon tetrachloride | | Ether | | 95% Alcohol | |
|---|---|---|---|---|---|---|---|
| °C | % | °C | % | °C | % | °C | % |
| 0 | 0.0050 | 0 | 0.007 | 0 | 0.188 | 0 | 0.320 |
| 20 | 0.0075 | 20 | 0.015 | 10 | 0.330 | 10 | 0.425 |
| 40 | 0.0110 | 40 | 0.058 | 20 | 0.418 | 20 | 0.563 |
| 80 | 0.0810 | 60 | 0.154 | 30 | 0.493 | 30 | 0.76 |
| 100 | 0.184 | | | | | 50 | 1.72 |
| | | | | | | 75 | 5.33 |

| Chloroform | | Carbon disulfide | | Ethylene dichloride | | Acetone | |
|---|---|---|---|---|---|---|---|
| °C | % | °C | % | °C | % | °C | % |
| 0 | 0.28 | 0 | 0.009 | 25 | 4.5 | 20 | 75 |
| 20 | 0.39 | 10 | 0.015 | 75 | 45 | 30 | 95 |
| 40 | 1.20 | 20 | 0.021 | | | 40 | 116 |
| 60 | 2.65 | 30 | 0.030 | | | 50 | 138 |

| Trichloroethylene | | Ethyl acetate | | Benzene | | Toluene | |
|---|---|---|---|---|---|---|---|
| °C | % | °C | % | °C | % | °C | % |
| 0 | 0.07 | 20 | ~40 | 20 | 7.8 | 20 | 8.5 |
| 20 | 0.12 | | | 30 | 10.0 | | |
| 40 | 0.26 | | | 40 | 12.5 | | |
| 60 | 0.67 | | | 50 | 16.0 | | |
| 80 | 1.50 | | | | | | |
| 86 | 1.76 | | | | | | |

| Xylene | | TNT | |
|---|---|---|---|
| °C | % | °C | % |
| 20 | 3.3 | 80 | 82 |
| 30 | 4.4 | 100 | 149 |
| 40 | 5.4 | 120 | 645 |
| 50 | 6.0 | | |

Origin:

Tetryl was first described in 1879 by Michler and Meyer (Ber 12, 1792), van Romburgh and Martens studied its properties and proved its structure (Rec trav chim 2, 108 (1883); 6, 215 (1887); and Ber 19, 2126 (1886)). Tetryl was not used as an explosive until World War I.

Destruction by Chemical Decomposition:

Tetryl is decomposed by dissolving in 12 times its weight of a solution prepared from 1 part by weight of sodium sulfite ($Na_2SO_3 \cdot 7H_2O$) in 4 parts water. The sulfite solution may be heated to 80°C to facilitate decomposition of the Tetryl.

References:[73]

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) Ph Naoum, Z ges Schiess---Sprengstoffw, pp. 181, 229, 267 (27 June 1932).

(c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(d) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303; 15 June 1949.

(e) C. A. Taylor and Wm. H. Rinkenbach, "The Solubility of Trinitro-Phenylmethyl-Nitramine (Tetryl) in Organic Solvents," J Am Chem Soc 45, (1923) p. 104.

(f) E. Hutchinson, The Thermal Sensitiveness of Explosives. The Thermal Conductivity of Explosive Materials, AC 2861, First Report, August 1942.

(g) R. J. Finkelstein and G. Gamow, Theory of the Detonation Process, NAVORD Report No. 90-46, 20 April 1947.

(h) M. A. Cook and M. T. Abegg, "Isothermal Decomposition of Explosives," University of Utah, Ind Eng Chem 1090-1095 (June 1956).

(i) J. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.

(j) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Different Temperatures, PATR No. 2383, November 1956.

(k) Also see the following Picatinny Arsenal Technical Reports on Tetryl:

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 30 | 11 | 132 | 453 | 84 | 65 | 266 | 117 | 28 | 129 |
| 600 | 361 | 582 | 493 | 144 | 195 | 556 | 197 | 438 | 179 |
| 770 | 381 | 832 | 623 | 294 | 425 | 786 | 637 | 628 | 319 |
| 810 | 621 | 882 | 833 | 314 | 525 | 986 | 707 | 708 | 609 |
| 1180 | 861 | 1192 | 863 | 694 | 565 | 1086 | 807 | 788 | 709 |
| 1290 | 1041 | 1352 | 1113 | 774 | 625 | 1126 | 837 | 838 | 849 |
| 1350 | 1131 | 1372 | 1373 | 784 | 635 | 1316 | 857 | 1418 | 999 |
| 1360 | 1261 | 1402 | 2053 | 874 | 845 | 1376 | 1047 | 1788 | 1029 |
| 1400 | 1311 | 1452 | 2163 | 904 | 925 | 1416 | 1137 | 1828 | 1209 |
| 1450 | 1431 | 1592 | 2233 | 1134 | 1145 | 1446 | 1287 | 1838 | 1379 |
| 1500 | 1471 | | | 1164 | 1285 | 1466 | 1337 | | 1429 |
| 1510 | 1611 | | | 1234 | 1405 | 1556 | 1367 | | 1489 |
| 1670 | 1651 | | | 1264 | 1585 | 1636 | 1437 | | 1819 |
| | | | | 2024 | 1885 | 1956 | 1737 | | 1969 |
| | | | | 2204 | 1935 | | 1797 | | |
| | | | | | 2105 | | 1937 | | |
| | | | | | 2125 | | | | |
| | | | | | 2205 | | | | |

[73] See footnote 1, page 10.

**Composition:**

| % | |
|---|---|
| Tetryl | 80 |
| TNT | 20 |

C/H Ratio

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 28 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 9 |
| Sample Wt, mg | 17 |

**Friction Pendulum Test:**

Steel Shoe

Fiber Shoe

**Rifle Bullet Impact Test:** Trials

| | % |
|---|---|
| Explosions | 0 |
| Partials | 20 |
| Burned | 0 |
| Unaffected | 80 |

**Explosion Temperature:** °C

Seconds, 0.1 (no cap used)

| | | |
|---|---|---|
| 1 | | |
| 5 | Ignites | 290 |
| 10 | | |
| 15 | | |
| 20 | | |

**75°C International Heat Test:**

% Loss in 48 Hrs

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.1 |
| % Loss, 2nd 48 Hrs | 0.5 |
| Explosion in 100 Hrs | None |

**Flammability Index:** Will not continue to burn

**Hygroscopicity:** % 0.02

**Volatility:**

**Molecular Weight:** 274

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -52 |
| CO % | -11 |

**Density:** gm/cc Cast 1.51

**Melting Point:** °C 68

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Vacuum Stability Test:**

cc/40 Hrs, at

| | |
|---|---|
| 90°C | |
| 100°C | 3.0 |
| 120°C | 11+ |
| 135°C | |
| 150°C | |

**200 Gram Bomb Sand Test:**

Sand, gm 54.0

**Sensitivity to Initiation:**

Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | 0.22* |
| Lead Azide | 0.17* |
| Tetryl | |

*Alternative initiating charges.

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**Plate Dent Test:**

Method

Condition

Confined

Density, gm/cc

Brisance, % TNT

**Detonation Rate:**

Confinement

Condition

Charge Diameter, in.

Density, gm/cc

Rate, meters/second

Tetrytol, 80/20

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Light yellow to buff

**Principal Uses:** Bursters, demolition blocks

**Method of Loading:**

**Loading Density:** gm/cc

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | Exudes at 65°C |

**Composition:**

| % | |
|---|---|
| Tetryl | 75 |
| TNT | 25 |

C/H Ratio

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 28 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 10 |
| Sample Wt, mg | 17 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Cracks |
| Fiber Shoe | Unaffected |

**Rifle Bullet Impact Test:**

| Trials | % |
|---|---|
| Explosions | 0 |
| Partials | 30 |
| Burned | 0 |
| Unaffected | 70 |

**Explosion Temperature:** °C

Seconds, 0.1 (no cap used)

| | | |
|---|---|---|
| 1 | | |
| 5 | Ignites | 310 |
| 10 | | |
| 15 | | |
| 20 | | |

**75°C International Heat Test:**

% Loss in 48 Hrs

**100°C Heat Test:**

% Loss, 1st 48 Hrs

% Loss, 2nd 48 Hrs

Explosion in 100 Hrs

**Flammability Index:** Will not continue to burn

**Hygroscopicity:** % 0.03

**Volatility:**

**Molecular Weight:** 270

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -54 |
| CO % | -12 |

**Density:** gm/cc Cast 1.59

**Melting Point:** °C 68

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Vacuum Stability Test:**

cc/40 Hrs, at

| | |
|---|---|
| 90°C | |
| 100°C | 3.0 |
| 120°C | 11+ |
| 135°C | |
| 150°C | |

**200 Gram Bomb Sand Test:**

Sand, gm 53.7

**Sensitivity to Initiation:**

Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | 0.23* |
| Lead Azide | 0.19* |
| Tetryl | |

*Alternative initiating charges.

**Ballistic Mortar, % TNT:** (a) 122

**Trauzl Test, % TNT:**

**Plate Dent Test:**

| | (b) | |
|---|---|---|
| Method | B | B |
| Condition | Cast | Cast |
| Confined | No | Yes |
| Density, gm/cc | 1.66 | 1.62 |
| Brisance, % TNT | 118 | 114 |

**Detonation Rate:**

| | |
|---|---|
| Confinement | None |
| Condition | Cast |
| Charge Diameter, in. | 1.0 |
| Density, gm/cc | 1.60 |
| Rate, meters/second | 7385 |

# Tetrytol, 75/25

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

| | |
|---|---|
| Density, gm/cc | 1.59 |
| Charge Wt, lb | 2.101 |

**Total No. of Fragments:**

| | |
|---|---|
| For TNT | 703 |
| For Subject HE | 857 |

**3 inch HE, M42A1 Projectile, Lot KC-5:**

| | |
|---|---|
| Density, gm/cc | 1.60 |
| Charge Wt, lb | 0.845 |

**Total No. of Fragments:**

| | |
|---|---|
| For TNT | 514 |
| For Subject HE | 591 |

**Fragment Velocity:** ft/sec

At 9 ft

At 25½ ft

Density, gm/cc

**Blast (Relative to TNT):**

**Air:**

Peak Pressure

Impulse

Energy

**Air, Confined:**

Impulse

**Under Water:**

Peak Pressure

Impulse

Energy

**Underground:**

Peak Pressure

Impulse

Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones (d) |
|---|---|---|
| Hole Volume | 127 | |
| Hole Depth | 120 | |

**Color:** Light yellow to buff

**Principal Uses:** Bursters, demolition blocks

**Method of Loading:** Cast

**Loading Density:** gm/cc 1.59

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | Exudes at 65°C |

Eutectic Temperature, °C: 67.5

gm Tetryl/100 gm TNT
67.5°C 54-82

Booster Sensitivity Test: (c)

| | |
|---|---|
| Condition | Cast |
| Tetryl, gm | 100 |
| Wax, in. for 50% Detonation | 1.66 |
| Density, gm/cc | 1.66 |

**Composition:**

| % | |
|---|---|
| Tetryl | 70 |
| TNT | 30 |

C/H Ratio

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 28 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 11 |
| Sample Wt, mg | 18 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | Unaffected |

**Rifle Bullet Impact Test:** Trials

| | % |
|---|---|
| Explosions | 0 |
| Partials | 55 |
| Burned | 0 |
| Unaffected | 45 |

**Explosion Temperature:**

| Seconds, 0.1 (no cap used) | °C 416 |
|---|---|
| 1 | 387 |
| 5 Ignites | 320 |
| 10 | 302 |
| 15 | 289 |
| 20 | 275 |

**75°C International Heat Test:**
% Loss in 48 Hrs

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.1 |
| % Loss, 2nd 48 Hrs | 0.1 |
| Explosion in 100 Hrs | None |

**Flammability Index:** Will not continue to burn

**Hygroscopicity:** % 0.02

**Volatility:**

**Molecular Weight:** 266

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -55 |
| CO % | -13 |

**Density:** gm/cc Cast 1.60

**Melting Point:** °C 68

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Vacuum Stability Test:**
cc/40 Hrs, at

| | |
|---|---|
| 90°C | |
| 100°C | 3.2 |
| 120°C | 11+ |
| 135°C | |
| 150°C | |

**200 Gram Bomb Sand Test:**

| | |
|---|---|
| Sand, gm | 53.2 |

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | 0.23* |
| Lead Azide | 0.22* |
| Tetryl | |

*Alternative initiating charges.

**Ballistic Mortar, % TNT:** (a) 120

**Trauzl Test, % TNT:**

**Plate Dent Test:** (b)

| | |
|---|---|
| Method | B |
| Condition | Cast |
| Confined | Yes |
| Density, gm/cc | 1.60 |
| Brisance, % TNT | 117 |

**Detonation Rate:**

| | |
|---|---|
| Confinement | None |
| Condition | Cast |
| Charge Diameter, in. | 1.0 |
| Density, gm/cc | 1.60 |
| Rate, meters/second | 7340 |

# Tetrytol, 70/30

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

| | |
|---|---|
| Density, gm/cc | 1.60 |
| Charge Wt, lb | 2.090 |

**Total No. of Fragments:**

| | |
|---|---|
| For TNT | 703 |
| For Subject HE | 840 |

**3 inch HE, M42A1 Projectile, Lot KC-5:**

| | |
|---|---|
| Density, gm/cc | 1.60 |
| Charge Wt, lb | 0.842 |

**Total No. of Fragments:**

| | |
|---|---|
| For TNT | 514 |
| For Subject HE | 585 |

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Light yellow to buff

**Principal Uses:** Bursters, demolition blocks

**Method of Loading:** Cast

**Loading Density:** gm/cc 1.60

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | Exudes at 65°C |

# Tetrytol, 65/35

**Composition:**
%

| | |
|---|---|
| Tetryl | 65 |
| TNT | 35 |

C/H Ratio

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 28 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 11 |
| Sample Wt, mg | 17 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Cracks |
| Fiber Shoe | Unaffected |

**Rifle Bullet Impact Test:** Trials

| | % |
|---|---|
| Explosions | 0 |
| Partials | 10 |
| Burned | 0 |
| Unaffected | 90 |

**Explosion Temperature:** °C

Seconds, 0.1 (no cap used)

| | | |
|---|---|---|
| 1 | | |
| 5 | Ignites | 325 |
| 10 | | |
| 15 | | |
| 20 | | |

**75°C International Heat Test:**
% Loss in 48 Hrs

**100°C Heat Test:**
% Loss, 1st 48 Hrs
% Loss, 2nd 48 Hrs
Explosion in 100 Hrs

**Flammability Index:** Will not continue to burn

**Hygroscopicity:** % 0.02

**Volatility:**

**Molecular Weight:** 264

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -56 |
| CO % | -14 |

**Density:** gm/cc 1.60

**Melting Point:** °C 68

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$
$n_{25}^{D}$
$n_{30}^{D}$

**Vacuum Stability Test:**
cc/40 Hrs, at

| | |
|---|---|
| 90°C | |
| 100°C | 2.8 |
| 120°C | 11+ |
| 135°C | |
| 150°C | |

**200 Gram Bomb Sand Test:**
Sand, gm 52.6

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | 0.23* |
| Lead Azide | 0.23* |
| Tetryl | |

*Alternative initiating charges.

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**Plate Dent Test:**
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**Detonation Rate:**

| | |
|---|---|
| Confinement | None |
| Condition | Cast |
| Charge Diameter, in. | 1.0 |
| Density, gm/cc | 1.60 |
| Rate, meters/second | 7310 |

# Tetrytol, 65/35

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

| | |
|---|---|
| Density, gm/cc | 1.61 |
| Charge Wt, lb | 2.010 |

**Total No. of Fragments:**

| | |
|---|---|
| For TNT | 703 |
| For Subject HE | 856 |

**3 inch HE, M42A1 Projectile, Lot KC-5:**

| | |
|---|---|
| Density, gm/cc | 1.60 |
| Charge Wt, lb | 0.845 |

**Total No. of Fragments:**

| | |
|---|---|
| For TNT | 514 |
| For Subject HE | 585 |

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | (d) Glass Cones | (e) Steel Cones |
|---|---|---|
| Hole Volume | 133 | 126 |
| Hole Depth | 120 | 119 |

**Color:** Light yellow to buff

**Principal Uses:** Bursters, demolition blocks

**Method of Loading:** Cast

**Loading Density:** gm/cc 1.60

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | Exudes at 65°C |

## Tetrytol, 80/20, 75/25, 70/30, 65/35

**Compatibility with Metals:**

Dry: Copper, brass, aluminum, magnesium, stainless steel, mild steel, mild steel coated with acid proof black paint and mild steel plated with copper, cadmium, zinc or nickel are unaffected. Magnesium-aluminum alloy is slightly affected.

Wet: Stainless steel and mild steel coated with acid-proof black paint are unaffected. Copper, brass, aluminum, magnesium, magnesium-aluminum alloy, mild steel and mild steel plated with cadmium, copper, zinc or nickel are slightly affected.

**Preparation:**

Tetrytols are manufactured by heating TNT in a melting kettle, equipped with a stirrer, until all the TNT is melted. The necessary amount of tetryl is added and heating and stirring are continued. The temperature is allowed to drop from 100°C until the mixture is of maximum viscosity suitable for pouring. Part of the tetryl dissolves in TNT forming a eutectic mixture which contains 55 percent tetryl. This mixture freezes at 67.5°C.

**Origin:**

Tetrytols were developed during World War II. The 70/30 tetryl/TNT castable mixture is the most important in military applications.

**References:**[74]

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III, Miscellaneous Sensitivity Tests, Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(c) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

(d) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition, NDRC Contract W672-ORD-5723.

(e) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Final Report, Eastern Lab, du Pont, 18 September 1943, NDRC Contract W-672-ORD-5723.

(f) Also see the following Picatinny Arsenal Technical Reports on Tetrytol:

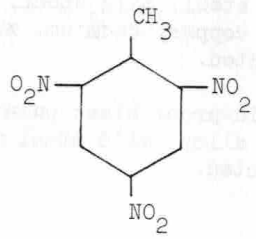
| 0 | 1 | 2 | 3 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| 1260 | 1291 | 1372 | 1193 | 1285 | 1376 | 1477 | 1158 | 1379 |
| 1360 | 1311 | | 1213 | 1325 | 1436 | 1737 | 1388 | |
| 1420 | 1451 | | 1363 | 1885 | 1466 | 1797 | 1838 | |
| 1500 | 1651 | | 1493 | 2125 | 1506 | | | |
| 1530 | 1951 | | | | | | | |

[74] See footnote 1, page 10.

# TNT (Trinitrotoluene)

**Composition:**

| | % |
|---|---|
| C | 37.0 |
| H | 2.2 |
| N | 18.5 |
| O | 42.3 |
| C/H Ratio | 0.549 |




**Molecular Weight:** ($C_7H_5N_3O_6$) 227

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -74 |
| CO % | -25 |

**Density:** gm/cc Crystal 1.65

**Melting Point:** °C 81

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$

| | |
|---|---|
| α | 1.5430 |
| β | 1.6742 |
| γ | 1.717 |

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 95-100+ |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 14-15 |
| Sample Wt, mg | 17 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | Unaffected |

**Vacuum Stability Test:**

cc/40 Hrs, at

| | |
|---|---|
| 90°C | |
| 100°C | 0.10 |
| 120°C | 0.23 |
| 135°C | 0.44 |
| 150°C | 0.65 |

**Rifle Bullet Impact Test:**

| | Trials | % |
|---|---|---|
| Explosions | 4 | |
| Partials | 0 | |
| Burned | 0 | |
| Unaffected | 6 | |

**200 Gram Bomb Sand Test:**

Sand, gm 48.0

**Explosion Temperature:**

| Seconds, 0.1 (no cap used) | °C |
|---|---|
| 1 | 570 |
| 5 Decomposes | 520 |
| 10 | 475 |
| 15 | 465 |
| 20 | |

**Sensitivity to Initiation:**

Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | 0.24* |
| Lead Azide | 0.27* |
| Tetryl | |

*Alternative initiating charges.

**Ballistic Mortar, % TNT:** Std=100

**Trauzl Test, % TNT:** Std=100

**75°C International Heat Test:**

% Loss in 48 Hrs 0.04

**Plate Dent Test:**

| | (a) | | |
|---|---|---|---|
| Method | A | A | B |
| Condition | Cast | Pressed | Cast |
| Confined | Yes | Yes | No |
| Density, gm/cc | 1.61 | 1.50 | 1.61 |
| Brisance, % TNT | 100 | 100 | 100 |

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.2 |
| % Loss, 2nd 48 Hrs | 0.2 |
| Explosion in 100 Hrs | None |

**Detonation Rate:**

| | | |
|---|---|---|
| Confinement | Unconfined | Unconfined |
| Condition | Pressed | Cast |
| Charge Diameter, in. | 1.0 | 1.0 |
| Density, gm/cc | 1.56 | 1.56 |
| Rate, meters/second | 6825 | 6640 |

**Flammability Index:** (b) 100

**Hygroscopicity:** % 30°C, 90% RH 0.03

**Volatility:** 30°C Nil

**Booster Sensitivity Test:** (c)

| Condition | Pressed | Cast |
|---|---|---|
| Tetryl, gm | 100 | 100 |
| Wax, in. for 50% Detonation | 1.68 | 0.82 |
| Wax, gm | | |
| Density, gm/cc | 1.55 | 1.60 |

**Heat of:** (d)

| | |
|---|---|
| Combustion, cal/gm | 3620 |
| Explosion, cal/gm | 1080 |
| Gas Volume, cc/gm | 730 |
| Formation, cal/gm | 78.5 |
| Fusion, cal/gm | 22.34 |
| Temperature, °C | 79 |

**Specific Heat:** cal/gm/°C

| °C | |
|---|---|
| 0 | 0.309 |
| 20 | 0.328 |
| 50 | 0.353 |
| 80 | 0.374 |

**Burning Rate:**
cm/sec

**Thermal Conductivity:**
cal/sec/cm/°C See next page.

**Coefficient of Expansion:** (b)

Linear, %/°C $-40^{\circ}$ to $60^{\circ}$C $5.4 \times 10^{-5}$ (b)
$-40^{\circ}$ to $60^{\circ}$C $6.7 \times 10^{-5}$

Volume, %/°C $27^{\circ}$ to $80^{\circ}$C $16 \times 10^{-5}$ (b)
$16^{\circ}$ to $70^{\circ}$C $26.3 \times 10^{-5}$ (n)

**Hardness, Mohs' Scale:** (e) 1.4

**Young's Modulus:** (b)

| | |
|---|---|
| E', dynes/cm² | $5.45 \times 10^{10}$ |
| E, lb/inch² | $0.79 \times 10^{6}$ |
| Density, gm/cc | 161 |

**Compressive Strength:** lb/inch² 13800-14000
Density, gm/cc 1.62

**Vapor Pressure:** (f)

| °C | mm Mercury |
|---|---|
| 80 | 0.042 |
| 85 | 0.053 |
| 90 | 0.067 |
| 95 | 0.085 |
| 100 | 0.106 |

**Decomposition Equation:** (h) (i)

| | | |
|---|---|---|
| Oxygen, atoms/sec (Z/sec) | $10^{11.4}$ | $10^{12.2}$ |
| Heat, kilocalorie/mole (ΔH, kcal/mol) | 34.4 | 43.4 |
| Temperature Range, °C | 275-310 | 238-277 |
| Phase | Liquid | Liquid |

**Armor Plate Impact Test:**

**60 mm Mortar Projectile:** (j)
50% Inert, Velocity, ft/sec >1100
Aluminum Fineness

**500-lb General Purpose Bombs:** (j)

| Plate Thickness, inches | Trials | % Inert |
|---|---|---|
| 1 | 0 | |
| 1¼ | 0 | |
| 1½ | 4 | 100 |
| 1¾ | 4 | 50 |

**Bomb Drop Test:**

**T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:**

Max Safe Drop, ft 5000-6000

**500-lb General Purpose Bomb vs Concrete:**

| | No Seal | Seal |
|---|---|---|
| Height, ft | 4,000 | 4-5,000 |
| Trials | 26 | 20 |
| Unaffected | 24 | 20 |
| Low Order | 2 | 0 |
| High Order | 0 | 0 |

**1000-lb General Purpose Bomb vs Concrete:**

| | No Seal | Seal |
|---|---|---|
| Height, ft | 5,000 | 5,000 |
| Trials | 21 | 26 |
| Unaffected | 18 | 22 |
| Low Order | 0 | 0 |
| High Order | 3 | 4 |

# TNT (Trinitrotoluene)

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

| | |
|---|---|
| Density, gm/cc | 1.60 |
| Charge Wt, lb | 2.104 |

**Total No. of Fragments:**

| | |
|---|---|
| For TNT | 703 |
| For Subject HE | 703 |

**3 inch HE, M42A1 Projectile, Lot KC-5:**

| | |
|---|---|
| Density, gm/cc | 1.60 |
| Charge Wt, lb | 0.848 |

**Total No. of Fragments:**

| | |
|---|---|
| For TNT | 514 |
| For Subject HE | 514 |

**Fragment Velocity:** ft/sec (k)

| | |
|---|---|
| At 9 ft | 2600 |
| At 25½ ft | 2360 |
| Density, gm/cc | 1.58 |

**Blast (Relative to TNT):**

| | |
|---|---|
| **Air:** | |
| Peak Pressure | 100 |
| Impulse | 100 |
| Energy | 100 |
| **Air, Confined:** | |
| Impulse | 100 |
| **Under Water:** | |
| Peak Pressure | 100 |
| Impulse | 100 |
| Energy | 100 |
| **Underground:** | |
| Peak Pressure | 100 |
| Impulse | 100 |
| Energy | 100 |

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | 100 | 100 |
| Hole Depth | 100 | 100 |

**Color:** Light yellow

**Principal Uses:** GP bombs, HE projectiles, demolition charges, depth charges, grenades, propellant compositions

**Method of Loading:**
1. Cast
2. Pressed

**Loading Density:** gm/cc — See below

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | None at 65°C |

Loading Density: gm/cc

1. Cast 1.58-1.59 2. Pressed psi x $10^3$

| 3 | 5 | 10 | 15 | 20 | 30 | 50 |
|---|---|---|---|---|---|---|
| 1.35 | 1.40 | 1.45 | 1.52 | 1.55 | 1.59 | 1.6 |

Thermal Conductivity:

cal/sec/cm/°C

| | |
|---|---|
| Density 1.19 gm/cc (g) | 5.28 x $10^{-4}$ |
| 1.51 gm/cc (g) | 7.12 x $10^{-4}$ |
| 1.54 gm/cc (b) | 5.6 x $10^{-4}$ |
| 1.67 gm/cc (g) | 12.21 x $10^{-4}$ |

Viscosity, poises:

| | |
|---|---|
| Temp, 85°C | 0.139 |
| 100°C | 0.095 |

Bulk Modulus at Room Temperature (25°-30°C): (m)

| | |
|---|---|
| Dynes/$cm^2$ x $10^{-10}$ | 2.92 |
| Density, gm/cc | 1.56 |

## TNT (Trinitrotoluene)

Effect of Temperature on Rate of Detonation: (1)

| Temperature of Charge, °C | -54 | 21 | 60 | 60 |
|---|---|---|---|---|
| Hours at Temperature | 16 | 16 | 24 | 72 |
| Density, gm/cc | 1.63 | 1.62 | 1.64 | 1.64 |
| Rate, meters/second | 6700 | 6820 | 6770 | 6510 |

Sensitivity to Electrostatic Discharge, Joules; Through 100 Mesh:

| | |
|---|---|
| Unconfined | 0.06 |
| Confined | 4.4 |

Impact Sensitivity versus Temperature:

Picatinny Arsenal Apparatus, 2 kg wt, inches:

| °C | inches |
|---|---|
| -40 | 17 |
| Room | 14 |
| 80 | 7 |
| 90 | 3 |
| 105-110 | 2 (5 expl in 20 trials) |

Impact Sensitivity versus Loading Method, Large Impact Apparatus, Inches:

| | |
|---|---|
| Pressed at 1.60 gm/cc | 70 |
| Cast at 1.60 gm/cc | 26 |

Rifle Bullet Impact Sensitivity versus Temperature, Confinement:

| Standard Iron Bomb: | Room Temperature | 105° to 110°C |
|---|---|---|
| No Air Space | | |
| Trials | 10 | 10 |
| Explosions | 1 very low order | 7 |
| Air Space | | |
| Trials | 10 | 10 |
| Explosions | 0 | 0 |
| Tin or Cardboard Bombs: | | |
| With or Without Air Space | | |
| Trials | 10 | 10 |
| Explosions | 0 | 0 |

Explosion Temperature versus TNT Initial Temperature:

| TNT Temperature, Initial | Explosion Temperature, °C |
|---|---|
| Room | 470 (Decomposes) |
| 105°-100°C | 480 (Decomposes) |

Explosion Temperature versus Confinement, °C:

| | | |
|---|---|---|
| Unconfined | Decomposes | 470 |
| Sealed in glass capillary | Explodes | 320-335 |

Viscosity at 80.5°C:

Viscosity, X, cp log X = 0.046 S + 1.26
S = % solid in slurry
Particle size effect, small

Density, gm/cc:

| °C | State | gm/cc |
|---|---|---|
| 27 to 70 | Flaked | 1.65 |
| 80 | Flaked | 1.64 |
| 82 | Liquid | 1.48 |
| 87 | Liquid | 1.48 |
| 95 | Liquid | 1.47 |

Solubility of TNT, gm/100 gm (%), in: (f)

| Water | | Acetone | | Benzene | | Toluene | |
|---|---|---|---|---|---|---|---|
| °C | % | °C | % | °C | % | °C | % |
| 0 | 0.0100 | 0 | 57 | 0 | 13 | 0 | 28 |
| 20 | 0.0130 | 20 | 109 | 20 | 67 | 20 | 55 |
| 40 | 0.0285 | 40 | 228 | 40 | 180 | 40 | 130 |
| 60 | 0.0675 | 60 | 600 | 60 | 478 | 60 | 367 |
| | | | | 80 | >2000 | 80 | >1700 |

| Carbon tetrachloride | | Ether | | Chloroform | | Trichloro-ethylene | |
|---|---|---|---|---|---|---|---|
| °C | % | °C | % | °C | % | °C | % |
| 0 | 0.20 | 0 | 1.73 | 0 | 6 | 25 | 3.5 |
| 0 | 0.65 | 20 | 3.29 | 20 | 19 | 55 | 60 |
| 40 | 1.75 | | | 40 | 66 | | |
| 60 | 6.90 | | | 60 | 302 | | |
| 70 | 17.34 | | | | | | |
| 75 | 24.35 | | | | | | |

## TNT (Trinitrotoluene)

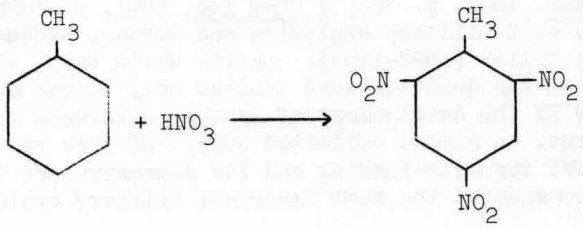
| Pyridine | | Methyl acetate | | Ethylene dichloride | | β-Ethoxy-ethyl-acetate | |
|---|---|---|---|---|---|---|---|
| °C | % | °C | % | °C | % | °C | % |
| 20 | 140 | 20 | 73 | 20 | 34 | 20 | 29.5 |
| 40 | 250 | 40 | 135 | 40 | 123 | 40 | 49 |
| 60 | 640 | 50 | 280 | 60 | 460 | 50 | 96 |
| 70 | 1250 | | | | | | |

| Tetrachloro-ethane | | Aniline | | Isopropyl alcohol | | Ethanol | |
|---|---|---|---|---|---|---|---|
| °C | % | °C | % | °C | % | °C | % |
| 20 | 18 | 10 | 6.1 | 20 | 0.76 | 0 | 0.62 |
| 40 | 50 | 30 | 11.5 | 40 | 1.96 | 20 | 1.25 |
| 50 | 100 | 50 | 29 | 50 | 2.95 | 40 | 2.85 |
| | | 70 | 74 | | | 60 | 8.4 |
| | | 80 | 130 | | | 70 | 15 |

| Isobutyl alcohol | | Carbon disulfide | | Chlorobenzene | |
|---|---|---|---|---|---|
| °C | % | °C | % | °C | % |
| 0 | 0.20 | 0 | 0.14 | 20 | 35 |
| 20 | 0.61 | 20 | 0.44 | 30 | 51 |
| 40 | 1.41 | 40 | 1.4 | 40 | 79 |
| 50 | 2.35 | | | 50 | 116 |

Preparation:

(AC 7258, 7259, 7260 - Nitration Kinetics)
(Chemistry of Powder and Explosives, Davis)




In older processes trinitrotoluene (TNT) was slowly and laboriously nitrated in three stages using successively stronger acids. Today, however, a single stage nitration is possible, in a short time (less than one hour) producing TNT at a cost of a little less than 6¢/lb. In England, a two stage continuous process was developed during World War II; in the first counter current stage, toluene was nitrated to the mono stage mononitrotoluene (MNT); in the second stage, also counter current, MNB was nitrated to TNT.

## TNT (Trinitrotoluene)

It was the British work, on the kinetics of nitration of toluene to TNT, that first pointed out the basic importance to nitration processes of the nitroxyl ion ($NO_2^+$), on the one hand, and the role of the bisulfate ion ($HSO_4^-$) and unionized sulfuric acid on the other. These concepts were successful in explaining the maximum in nitration rate occurring at a sulfuric acid content of 92%. This work, for instance, leads to the following equation for the rate of formation of TNT from DNT:

$$\frac{d\,(TNT)}{dt} = K\,(NO_2^+)\;\left[K'\,(HSO_4^-) + K''\,(H_2SO_4)\right]\,(DNT)$$

Three Stage Process: Toluene (100 gm) is nitrated to the mono derivative by slowly adding a mixture of 294 gm sulfuric acid (sp gr 1.84) and 147 gm nitric acid (sp gr 1.42) to it at 30°-40°C, with good agitation. Acid addition requires 1-1.5 hour, and stirring at 30°-40°C is continued 30 minutes longer. The mixture is cooled and the lower layer of spent acid drawn off.

Half the crude mono is dissolved in 109 gm sulfuric acid (sp gr 1.84) with cooling, the solution heated to 50°C and a mixture of 54.5 gm nitric acid (sp gr 1.50) and 54.5 gm sulfuric acid (sp gr 1.84) added, under agitation, at such a rate that the temperature is maintained between 90° and 100°C. Acid addition requires 1 hour, and stirring at 90°-100°C is continued 2 more hours.

While the dinitration mixture is still at 90°C, 145 gm fuming sulfuric acid (oleum containing 15% free $SO_3$) is added slowly. A mixed acid of 92.5 gm each nitric acid (sp gr 1.50) and 15% oleum is slowly added, under good agitation at 100°-115°C over 1½-2 hours. The mixture is stirred at 100°-115°C for 2 more hours, cooled, filtered, and the TNT cake broken up and washed with water. The TNT is washed 3-4 times with hot water (85°-95°C) with good agitation. The product can be purified either by recrystallization from alcohol or by washing it with 5 times its weight of 5% sodium bisulfite solution at 90°C for ½ hour with vigorous stirring, washing with hot water until the washings are colorless, and cooling slowly with stirring to granulate the product.

Origin:

TNT was first prepared in 1863 by Wilbrand (Ann 128, 178), later by Beilstein and Kuhlberg (Ber 3, 202 (1870) and also Tiemann (Ber 3, 217 (1870), each using different methods of starting materials. It was nearly 30 years later when Hausermann undertook its manufacture on an industrial scale (Z angew Chem, 1891, p. 508; J Chem Ind, 1891, p. 1028). After 1901 TNT began to be used extensively as a military explosive and Germany became the first nation to adopt it as a standard shell filler (1902-1904). During World War I all the major powers of the world were using TNT, with the quantity used limited only by the available supply of toluene. Prior to World War II the development of synthetic toluene from petroleum made available in the United States, an almost unlimited supply of this raw material. Because of the general suitability of TNT for melt-loading and its extensive use in binary and ternary explosive mixtures, TNT is considered the most important military explosive known today.

Destruction by Chemical Decomposition:

TNT is decomposed by adding it slowly, while stirring, to 30 times its weight of a solution prepared by dissolving 1 part of sodium sulfide ($Na_2S \cdot 9H_2O$) in 6 parts of water.

References:[75]

(a) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

[75]See footnote 1, page 10.

(b) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.

(c) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

(d) L. C. Smith and E. H. Eyster, Physical Testing of Explosives, Part III, Miscellaneous Sensitivity Tests, Performance Tests, OSRD Report No. 5746, 27 December 1945.

(e) Report AC-2587.

(f) International Critical Tables and various other sources in the open literature.

(g) E. Hutchinson, The Thermal Sensitiveness of Explosives. The Thermal Conductivity of Explosive Materials, AC-2861, First Report, August 1942.

(h) A. J. B. Robertson, Trans Farad Society, 44, 977 (1948).

(i) M. A. Cook and M. T. Abegg,"Isothermal Decomposition of Explosives," University of Utah, Ind Eng Chem (June 1956), pp. 1090-1095.

(j) Committee of Div 2 and 8, NDRC, Report on HBX and Tritonal, OSRD No. 5406, 31 July 1945.

(k) R. W. Drake, Fragment Velocity and Panel Penetration of Several Explosives in Simulated Shells, OSRD Report No. 5622, 2 January 1946.

(l) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Different Temperatures, PATR No. 2383, November 1956.

(m) W. S. Cramer, Bulk Compressibility Data on Several High Explosives, NAVORD Report No. 4380, 15 September 1956.

(n) Mantrov, Journal of Chemical Industry (Russia) 6, 1929, pp. 1686-1688.

(o) Also see the following Picatinny Arsenal Technical Reports on TNT:

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 10 | 291 | 132 | 43 | 364 | 65 | 86 | 47 | 118 | 99 |
| 30 | 551 | 582 | 83 | 694 | 195 | 266 | 87 | 288 | 249 |
| 240 | 731 | 782 | 133 | 874 | 425 | 556 | 507 | 638 | 269 |
| 350 | 861 | 892 | 273 | 904 | 555 | 666 | 527 | 738 | 319 |
| 630 | 891 | 972 | 513 | 1094 | 695 | 956 | 597 | 768 | 389 |
| 760 | 901 | 1072 | 643 | 1104 | 735 | 986 | 707 | 838 | 499 |
| 810 | 971 | 1182 | 673 | 1124 | 805 | 1046 | 807 | 1088 | 709 |
| 1120 | 1041 | 1192 | 743 | 1224 | 975 | 1146 | 817 | 1098 | 739 |
| 1140 | 1121 | 1272 | 853 | 1284 | 1145 | 1276 | 837 | 1128 | 779 |
| 1170 | 1311 | 1292 | 863 | 1294 | 1155 | 1376 | 1107 | 1148 | 799 |
| 1260 | 1391 | 1342 | 1063 | 1304 | 1225 | 1446 | 1147 | 1158 | 889 |
| 1270 | 1431 | 1352 | 1123 | 1314 | 1285 | 1466 | 1217 | 1188 | 929 |
| 1360 | 1451 | 1372 | 1133 | 1344 | 1305 | 1476 | 1247 | 1198 | 939 |
| 1400 | 1491 | 1402 | 1193 | 1414 | 1315 | 1556 | 1307 | 1228 | 1099 |
| 1460 | 1651 | 1452 | 1243 | 1444 | 1395 | 1636 | 1417 | 1258 | 1109 |
| 1500 | 1821 | 1472 | 1323 | 1454 | 1425 | 1756 | 1427 | 1308 | 1129 |

## TNT (Trinitrotoluene)

| 0 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| 1530 | 1492 | 1373 | 1524 | 1435 | 1956 | 1437 | 1318 | 1139 |
| 1540 | 1562 | 1493 | 1544 | 1445 | 2216 | 1457 | 1338 | 1179 |
| 1550 | 1582 | 1553 | 1564 | 1495 | | 1497 | 1388 | 1199 |
| 1730 | 1712 | 1633 | 1604 | 1515 | | 1537 | 1418 | 1259 |
| 2010 | 1862 | 1693 | 1674 | 1535 | | 1547 | 1428 | 1289 |
| 2100 | | 1823 | 1754 | 1585 | | 1557 | 1578 | 1339 |
| 2160 | | 2063 | 1924 | 1605 | | 1577 | 1618 | 1369 |
| | | 2163 | 2064 | 1635 | | 1597 | 1688 | 1379 |
| | | | 2214 | 1665 | | 1677 | 1728 | 1419 |
| | | | | 1865 | | 1737 | 1828 | 1429 |
| | | | | 1965 | | 1797 | 1838 | 1469 |
| | | | | 1715 | | 1827 | 1858 | 1489 |
| | | | | 1885 | | 1847 | 2008 | 1529 |
| | | | | 2125 | | 2007 | 2138 | 1549 |
| | | | | 2175 | | 2147 | 2168 | 1629 |
| | | | | | | 2167 | | 1689 |
| | | | | | | | | 1709 |
| | | | | | | | | 1729 |
| | | | | | | | | 1749 |
| | | | | | | | | 1809 |
| | | | | | | | | 1819 |
| | | | | | | | | 1879 |
| | | | | | | | | 1949 |
| | | | | | | | | 2159 |
| | | | | | | | | 2179 |

# Torpex

**Composition:**

| | % |
|---|---|
| RDX | 42 |
| TNT | 40 |
| Aluminum | 18 |
| C/H Ratio | |

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 42 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 9 |
| Sample Wt, mg | 15 |

**Friction Pendulum Test:**

Steel Shoe

Fiber Shoe

**Rifle Bullet Impact Test:**

| | Trials | % |
|---|---|---|
| Explosions | | 20 |
| Partials | | 80 |
| Burned | | 0 |
| Unaffected | | 0 |

**Explosion Temperature:** °C

Seconds, 0.1 (no cap used)

| | | |
|---|---|---|
| 1 | | |
| 5 | Decomposes | 260 |
| 10 | | |
| 15 | | |
| 20 | | |

**75°C International Heat Test:**

% Loss in 48 Hrs

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.00 |
| % Loss, 2nd 48 Hrs | 0.10 |
| Explosion in 100 Hrs | None |

**Flammability Index:** 196

**Hygroscopicity:** % 30°C, 90% RH 0.00

**Volatility:**

**Molecular Weight:** 97

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -55 |
| CO % | -26 |

**Density:** gm/cc Cast 1.76-1.81

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Vacuum Stability Test:**

cc/40 Hrs, at

| | |
|---|---|
| 90°C | |
| 100°C | |
| 120°C | 1.0 |
| 135°C | |
| 150°C | |

**200 Gram Bomb Sand Test:**

Sand, gm 59.5

**Sensitivity to Initiation:**

Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | 0.18 |
| Lead Azide | |
| Tetryl | |

**Ballistic Mortar, % TNT:** (a) 138

**Trauzl Test, % TNT:** (b) 164

**Plate Dent Test:** (c)

| | |
|---|---|
| Method | B |
| Condition | Cast |
| Confined | No |
| Density, gm/cc | 1.83 |
| Brisance, % TNT | 120 |

**Detonation Rate:** (d)

| | |
|---|---|
| Confinement | None |
| Condition | Cast |
| Charge Diameter, in. | 1.0 |
| Density, gm/cc | 1.81 |
| Rate, meters/second | 7495 |

Torpex

**Booster Sensitivity Test:** (c)

| Condition | Pressed | Cast |
|---|---|---|
| Tetryl, gm | 10 | 5 |
| Wax, in. for 50% Detonation | | |
| Wax, gm | 2 | 0 |
| Density, gm/cc | 1.64 | 1.81 |

**Heat of:** (a)

| | |
|---|---|
| Combustion, cal/gm | 3740 |
| Explosion, cal/gm | 1800 |
| Gas Volume, cc/gm | |
| Formation, cal/gm | |
| Fusion, cal/gm | |

**Specific Heat:** cal/gm/°C (b)

| | |
|---|---|
| At -5°C | 0.22 |
| Density, gm/cc | 1.82 |
| At 15°C | 0.24 |

**Burning Rate:**
cm/sec

**Thermal Conductivity:** (b)

| | |
|---|---|
| cal/sec/cm/°C | $9.7 \times 10^{-4}$ |
| Density, gm/cc | 1.82 |

**Coefficient of Expansion:**
Linear, %/°C -73° to 75°C $4.7 \times 10^{-5}$ (b)

Volume, %/°C

**Hardness, Mohs' Scale:**

**Young's Modulus:** (b)

| | |
|---|---|
| E', dynes/cm² | $9.53 \times 10^{10}$ |
| E, lb/inch² | $1.38 \times 10^{6}$ |
| Density, gm/cc | 1.77 |

**Compressive Strength:** lb/inch² (b) 2100-2300
Density, gm/cc 1.77

**Vapor Pressure:**
°C mm Mercury

**Decomposition Equation:**
Oxygen, atoms/sec (Z/sec)
Heat, kilocalorie/mole (ΔH, kcal/mol)
Temperature Range, °C
Phase

**Armor Plate Impact Test:**

**60 mm Mortar Projectile:** (a)
50% Inert, Velocity, ft/sec 185
Aluminum Fineness

**500-lb General Purpose Bombs:**

Plate Thickness, inches

1
1¼
1½
1¾

**Bomb Drop Test:**

**T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:**

Max Safe Drop, ft

**500-lb General Purpose Bomb vs Concrete:**

Height, ft
Trials
Unaffected
Low Order
High Order

**1000-lb General Purpose Bomb vs Concrete:**

Height, ft
Trials
Unaffected
Low Order
High Order

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

| | |
|---|---|
| Density, gm/cc | 1.75 |
| Charge Wt, lb | 2.316 |
| **Total No. of Fragments:** | |
| For TNT | 703 |
| For Subject HE | 891 |

**3 inch HE, M42A1 Projectile, Lot KC-5:**

| | |
|---|---|
| Density, gm/cc | 1.79 |
| Charge Wt, lb | 0.940 |
| **Total No. of Fragments:** | |
| For TNT | 514 |
| For Subject HE | 647 |

**Fragment Velocity:** ft/sec

| | |
|---|---|
| At 9 ft | 2960 |
| At 25½ ft | 2800 |
| Density, gm/cc | -- |

**Blast (Relative to TNT):** (e)

| | |
|---|---|
| **Air:** | |
| Peak Pressure | 122 |
| Impulse | 125 |
| Energy | 146 |
| **Air, Confined:** | |
| Impulse | 116 |
| **Under Water:** | |
| Peak Pressure | 116 |
| Impulse | 127 |
| Energy | 153 |
| **Underground:** | |
| Peak Pressure | |
| Impulse | |
| Energy | |

**Shaped Charge Effectiveness, TNT = 100:** 50/36.5/13.5

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | 150 | 145 |
| Hole Depth | 127 | 131 |

**Color:** Gray

**Principal Uses:** Depth charges, bombs

**Method of Loading:** Cast

**Loading Density:** gm/cc 1.76-1.81

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | |

Effect of Temperature on Impact Sensitivity:

| Temp. °C | PA Impact Test 2 Kg Wt, inches |
|---|---|
| 25 | 15 |
| 32 | 7 |
| 104 | 8 |

Viscosity, poises:

| | |
|---|---|
| Temp, 83°C | 4.5 |
| 95°C | 2.3 |

## Torpex

Preparation:

Torpex is manufactured by heating TNT to approximately 100°C in a steam-jacketed kettle equipped with a stirrer. Water wet RDX is added slowly to the molten TNT, while mixing and heating, until all the water is evaporated. Aluminum is added and the mixture is stirred until uniform. The mixture is cooled, with continued stirring, until it is suitable for pouring. Torpex can also be made by adding the calculated amount of TNT to Composition B to maintain the desired proportion of RDX/TNT, heating and stirring, and adding 18 percent of aluminum to complete the mixture.

Origin:

Torpex, a castable high explosive, was developed in England during World War II for use as a filler in warheads, mines and depth bombs. Several variations in the composition of torpex have been evaluated but the following are those used in service munitions:

| | Torpex 2 unwaxed (a) | Torpex 2 waxed (b) | Torpex 3 (c) |
|---|---|---|---|
| RDX, % | 42 | 41.6 | 41.4 |
| TNT, % | 40 | 39.7 | 39.5 |
| Aluminum, % | 18 | 18.0 | 17.9 |
| Wax, % | | 0.7 | 0.7 |
| Calcium chloride, % | | | 0.5 |

(a) Made from Composition B-2 or 60/40 Cyclotol.

(b) Made by the addition of aluminum to Composition B.

(c) Made by the addition of calcium chloride to Torpex 2.

Wax has the undesirable effect of (1) tending to coagulate the aluminum, thus giving a less homogeneous and more viscous product, (2) lowering the density of the cast explosive from 1.72-1.75 to 1.66-1.70 for waxed torpex, and (3) lowering the compressive strength from 3700 psi to 1970 psi for waxed torpex. However, wax is used in service torpex for reasons of safety, since there is evidence that its presence lowers the sensitivity of the explosive to impact as measured by laboratory drop tests and bullet sensitivity tests of small charges (Bureau of Ord Res Memo Rpt No. 24, January 1945).

References:[76]

(a) Committee of Div 2 and 8, NDRC, Report on HBX and Tritonal, OSRD No. 5406, 31 July 1945.

(b) Philip C. Keenan and Dorothy C. Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.

(c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

L. C. Smith and E. H. Eyster, Physical Testing of Explosives, Part III, Miscellaneous Sensitivity Tests, Performance Tests, OSRD Report No. 5746, 27 December 1945.

[76] See footnote 1, page 10.

(d) G. H. Messerly, The Rate of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.

M. D. Hurwitz, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1946.

(e) W. R. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Tech Div Lecture, 9 April 1948.

(f) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition, NDRC Contract W672-ORD-5723.

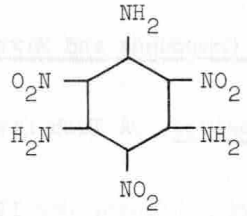
(g) Also see the following Picatinny Arsenal Technical Reports on Torpex:

| 0 | 1 | 2 | 3 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| 1530 | 1651 | 1292 | 2353 | 1585<br>1635<br>1885<br>2355 | 1796 | 1797 | 1838 |

# 1,3,5-Triamino-2,4,6-Trinitrobenzene (TATNB)

**Composition:**

| | % |
|---|---|
| C | 27.9 |
| H | 2.3 |
| N | 32.6 |
| O | 37.2 |



C/H Ratio 0.302

**Molecular Weight:** ($C_6H_6N_6O_6$) 258

**Oxygen Balance:**
- $CO_2$ % -56
- CO % -19

**Density:** gm/cc Crystal 1.93

**Melting Point:** °C 330 (b, e) 360 (a)

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Impact Sensitivity, 2 Kg Wt:**
- Bureau of Mines Apparatus, cm
  - Sample Wt 20 mg
- Picatinny Arsenal Apparatus, in. 11
  - Sample Wt, mg 7

**Friction Pendulum Test:**
- Steel Shoe
- Fiber Shoe

**Vacuum Stability Test:**
cc/40 Hrs, at

| | |
|---|---|
| 90°C | ---- |
| 100°C (a, b) | 0.36 |
| 120°C | ---- |
| 135°C | ---- |
| 150°C | ---- |

**Rifle Bullet Impact Test:** Trials %
- Explosions
- Partials
- Burned
- Unaffected

**200 Gram Bomb Sand Test:**
- Sand, gm 42.9

**Explosion Temperature:** °C
Seconds, 0.1 (no cap used)
- 1
- 5
- 10
- 15
- 20

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | ---- |
| Lead Azide | 0.30 |
| Tetryl | ---- |

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**75°C International Heat Test:**
- % Loss in 48 Hrs

**Plate Dent Test:**
- Method
- Condition
- Confined
- Density, gm/cc
- Brisance, % TNT

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.00 |
| % Loss, 2nd 48 Hrs | 0.00 |
| Explosion in 100 Hrs | None |

**Detonation Rate:**

| | |
|---|---|
| Confinement | None |
| Condition | Pressed |
| Charge Diameter, in. | 0.5 |
| Density, gm/cc | 1.80 |
| Rate, meters/second | 7500 |

**Flammability Index:**

**Hygroscopicity:** %

**Volatility:**

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Yellow

**Principal Uses:**

**Method of Loading:** Pressed

**Loading Density:** gm/cc
At 50,000 psi 1.80

**Storage:**

Method Dry

Hazard Class (Quantity-Distance)

Compatibility Group

Exudation

Detonation Velocity: (a, b, c)

| Density, gm/cc | Meters/sec |
|---|---|
| 1.290 | 5380 |
| 1.345 | 5628 |
| 1.675 | 6550 |
| 1.675 | 6575 |
| 1.882 | 7035 |
| 1.835 | 7220 |

Heat of:

Explosion, cal/gm 2831

## 1,3,5-Triamino-2,4,6-Trinitrobenzene (TATNB)

Preparation: (a)

Absolute alcohol (200 milliliters) was saturated with ammonia and then 12.5 gm (0.028 mol) of 1,3,5-tribromo-2,4,6-trinitrobenzene, prepared according to Hill (NAVORD Report No. 3709, 2 February 1953), was added. The flask was stoppered and allowed to stand at room temperature for a day. Additional ammonia was bubbled into the mixture, which was then heated under reflux for thirty minutes, filtered hot, and the insoluble product collected on a Buchner funnel. The product was washed with water, alcohol, and dried. The 4.7 gm of material recovered was recrystallized from nitrobenzene.

A disadvantage of the above method was that it could not be used for the preparation of large quantities of TATNB. Since it did not seem feasible to develop a new method of preparation, an investigation was made of the reported amination reactions (see Origin below). An attempt was made (Ref f) to find a modification which would produce high yields of a pure product. The process which evolved from this study may be summarized as follows (Ref f): 1,3,5-trichlorobenzene was nitrated "in one step" to 1,3,5-trichloro-2,4,6-trinitrobenzene in 85% yield. The crude nitration product was aminated in benzene with ammonia gas to TATNB, in yields of at least 95%.

Origin:

TATNB was prepared for the first time in 1888 by C. L. Jackson and J. F. Wing, who found the compound insoluble in alcohol, ether, chloroform, benzene, and glacial acetic acid; and soluble in nitrobenzene and aniline (Amer Chem Journal 10, 282 (1888)). B. Flürscheim and E. L. Holmes prepared TATNB from benzene free pentanitroaniline by gradually adding it to 10% aqueous ammonia (J Chem Soc, Pt 2,3045 (1928)). After boiling, an orange-yellow powder melting above 300°C was obtained. This product corresponded to that described by Jackson and Wing. These authors, as well as Palmer (Amer Chem Journal 14, 378 (1892)), attempted to reduce TATNB to hexa-aminobenzene. Either decomposition occurred or a hydrochloride of penta-aminobenzene was formed. Flurscheim and Holmes succeeded in reducing TATNB with phenylhydrazine by heating them together up to 200°C (J Chem Soc, Pt 1,334 (1929)) (Beil 13, 301 and EII, 147).

References:[77]

(a) F. Taylor, Jr., Synthesis of New High Explosives II, Derivatives of 1,3,5-Tribromo-2,4,6-Trinitrobenzene, NAVORD Report No. 4405, 1 November 1956.

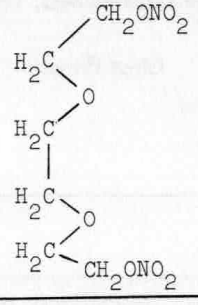
(b) L. D. Hampton, Small Scale Detonation Velocity Measurements from May 1951 to May 1954, NAVORD Report No. 3731, June 1954.

(c) E. M. Fisher and E. A. Christian, Explosion Effects Data Sheets, NAVORD Report No. 2986, 14 June 1955.

[77] See footnote 1, page 10.

**Composition:**

| | % |
|---|---|
| C | 29.9 |
| H | 5.4 |
| N | 11.7 |
| O | 53.0 |
| C/H Ratio | 0.177 |



**Molecular Weight:** $(C_6H_{12}N_2O_8)$ 240

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -89 |
| CO % | -27 |

**Density:** gm/cc

| | |
|---|---|
| 20°C | 1.33 |
| 25°C | 1.32 |

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^D$ 1.4540

$n_{25}^D$

$n_{30}^D$

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 100+ |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 43 |
| Sample Wt, mg | |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | Unaffected |

**Vacuum Stability Test:**

cc/40 Hrs, at

| | | |
|---|---|---|
| 90°C | | |
| 100°C | | 0.45 |
| 120°C | 8 hours | 0.8 |
| 135°C | | |
| 150°C | | |

**Rifle Bullet Impact Test:**

| | Trials | % |
|---|---|---|
| Explosions | | |
| Partials | | |
| Burned | | |
| Unaffected | | |

**200 Gram Bomb Sand Test:**

Sand, gm 14.7

**Explosion Temperature:** °C

Seconds, 0.1 (no cap used)

| | |
|---|---|
| 1 | |
| 5 | 223 |
| 10 | |
| 15 | |
| 20 | |

**Sensitivity to Initiation:**

Minimum Detonating Charge, gm

- Mercury Fulminate
- Lead Azide
- Tetryl

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**75°C International Heat Test:**

% Loss in 48 Hrs

**Plate Dent Test:**

- Method
- Condition
- Confined
- Density, gm/cc
- Brisance, % TNT

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 1.8 |
| % Loss, 2nd 48 Hrs | 1.6 |
| Explosion in 100 Hrs | None |

**Detonation Rate:**

| | |
|---|---|
| Confinement | Shelby steel |
| Condition | Liquid |
| Charge Diameter, in. | 1.25 |
| Density, gm/cc | 1.33 |
| Rate, meters/second | Fails |

**Flammability Index:**

**Hygroscopicity:** %

**Volatility:** 60°C, $mg/cm^2/hr$ 40

# Triethylene Glycol Dinitrate (TEGN) Liquid

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**Fragment Velocity:** ft/sec

At 9 ft

At 25½ ft

Density, gm/cc

**Blast (Relative to TNT):**

**Air:**

Peak Pressure

Impulse

Energy

**Air, Confined:**

Impulse

**Under Water:**

Peak Pressure

Impulse

Energy

**Underground:**

Peak Pressure

Impulse

Energy

Heat of:

| | |
|---|---|
| Combustion, cal/gm | 3428 |
| Explosion, cal/gm | 357 |
| Gas Volume, cc/gm | 851 |

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:**

**Principal Uses:** Ingredient of rocket and double base propellants

**Method of Loading:**

**Loading Density:** gm/cc

**Storage:**

| | |
|---|---|
| Method | Liquid |
| Hazard Class (Quantity-Distance) | |
| Compatibility Group | |
| Exudation | |

Solubility in Water, gm/100 gm, at:

| | |
|---|---|
| 25°C | 0.55 |
| 60°C | 0.68 |

Solubility, gm/100 gm, at 25°C, in:

| | |
|---|---|
| Ether | ∞ |
| Alcohol | ∞ |
| 2:1 Ether:Alcohol | ∞ |
| Acetone | ∞ |

Viscosity, centipoises:

| | |
|---|---|
| Temp, 20°C | 13.2 |

Hydrolysis, % Acid:

| | |
|---|---|
| 10 days at 22°C | 0.032 |
| 5 days at 60°C | 0.029 |

Vapor Pressure:

| °C | mm Mercury |
|---|---|
| 25 | <0.001 |

## Triethylene Glycol Dinitrate (TEGN) Liquid

### Origin:

Lourenco prepared triethylene glycol in 1863 by heating glycol with ethylene bromide in a sealed tube at 115°-120°C (Ann (3) 67, 275). Later in the same year Wurtz prepared triethylene glycol by heating ethylene oxide with glycol at 100°C. By action of nitric acid triethylene glycol was oxidized to $(H_2OOC \cdot CH_2 \cdot O\text{-}CH_2)_2$ (Ann (3) 69, 331, 351).

The Germans and Italians were the first to prepare and use TEGN during World War II as an ingredient of rocket and propellant powders. The commercial production of TEGN in quantity is still difficult and its use as a plasticizer for nitrocellulose is being replaced by other liquid nitrates.

### Preparation:

Triethylene glycol is purified by fractional distillation under vacuum in an 18-inch Vigeaux fractioning column. The assembly as a whole is equivalent to 4.5 theoretical plates. The distillation is conducted using a 5 to 1 reflux ratio, at a pot temperature of approximately 180°C, and a take-off temperature of approximately 120°C.

The purified triethylene glycol (TEG) is nitrated by carefully stirring it into 2.5 parts of 65/30/5 nitric acid/sulphuric acid/water maintained at 0 ± 5°C. The rate of cooling is sufficient that 300 gm of TEG can be added within 40 minutes. The mixture is stirred and held at 0 ± 5°C, for 30 additional minutes. It is then drowned by pouring onto a large quantity of ice and extracted three times with ether. The combined extract is water-washed to a pH of about 4, shaken with an excess of sodium bicarbonate solution, and further washed with 1% sodium bicarbonate solution until the washings are colorless. The ethereal solution is water-washed until it has the same pH value as distilled water. It is carefully separated from excess water, treated with chemically pure calcium chloride to remove dissolved water, and filtered. The ether is removed by bubbling with dry air until a minimal rate of loss in weight is attained. The yield is 1.34 gm per gm TEG (84% of theoretical) and the nitrogen content of different batches range from 11.60 to 11.69% by the nitrometer method (calculated 11.67%).

### References:[78]

(a) See the following Picatinny Arsenal Technical Reports on TEGN:

| 3 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|
| 1953 | 1745 | 1786 | 1767 | 1638 |
| 2193 | | 2056 | 1817 | |

[78] See footnote 1, page 10.

# Trimonite

**Composition:**
%

| | | |
|---|---|---|
| Picric Acid | 88 - 90 | |
| Mononitronaphthalene | 12 - 10 | |
| C/H Ratio | | |

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 60 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 10 |
| Sample Wt, mg | |

**Friction Pendulum Test:**
Steel Shoe
Fiber Shoe

**Rifle Bullet Impact Test:**

| | Trials % |
|---|---|
| Explosions | 0 |
| Partials | 0 |
| Burned | 0 |
| Unaffected | 100 |

**Explosion Temperature:** °C
Seconds, 0.1 (no cap used)

| | | |
|---|---|---|
| 1 | | |
| 5 | Decomposes | 315 |
| 10 | | |
| 15 | | |
| 20 | | |

**75°C International Heat Test:**
% Loss in 48 Hrs

**100°C Heat Test:**
% Loss, 1st 48 Hrs
% Loss, 2nd 48 Hrs
Explosion in 100 Hrs

**Flammability Index:**

**Hygroscopicity:** %

**Volatility:**

**Molecular Weight:** 217

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -62 |
| CO % | -14 |

**Density:** gm/cc Cast 1.60

**Melting Point:** °C 90

**Freezing Point:** °C

**Boiling Point:** °C Explodes 300

**Refractive Index,** $n_{20}^{D}$ $n_{25}^{D}$ $n_{30}^{D}$

**Vacuum Stability Test:**
cc/40 Hrs, at
90°C
100°C
120°C 0.9
135°C
150°C

**200 Gram Bomb Sand Test:**
Sand, gm 44.2

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | |
| Lead Azide | 0.20 |
| Tetryl | 0.04 |

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**Plate Dent Test:**
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**Detonation Rate:**

| | |
|---|---|
| Confinement | None |
| Condition | Cast |
| Charge Diameter, in. | 1.0 |
| Density, gm/cc | 1.60 |
| Rate, meters/second | 7020 |

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:**

**Principal Uses:** TNT substitute in projectiles and bombs

**Method of Loading:** Cast

**Loading Density:** gm/cc 1.60

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | Exudes at 50°C |

Preparation:

Picric acid and alpha-mononitronaphthalene are melted together in an aluminum or tin steam-jacketed melt kettle equipped with a stirrer. Although picric acid alone requires a high temperature for its melt loading (120°C), the mixture forms a eutectic melting at 49°C. Care must be taken to prevent the formation of dangerous metallic picrates. Trimonite is of interest as an emergency substitute for TNT.

## Trimonite

Origin:

Trimonite, a castable mixture of picric acid/mononitronaphthalene was developed by the British during World War II as an improvement over tridite which is a mixture of 80/20 picric acid/dinitrophenol. Both mixtures are suitable for melt-loading below 100°C and therefore represent an improvement over melt-loading picric acid alone (melting point 122°C). However, tridite is slightly inferior to picric acid as an explosive and dinitrophenol is objectionable because of its toxicity. Trimonite is also slightly inferior to picric acid and TNT as an explosive. Because of the low eutectic temperature of the picric acid-mononitronaphthalene mixture (49°C), Tridite exudes when stored at elevated temperatures. It does not possess the disadvantages of picric acid (corrosive action on metals, ease of decomposition, etc.) and is a comparatively inexpensive substitute for TNT.

References:[79]

(a) See the following Picatinny Arsenal Technical Reports on Trimonite:

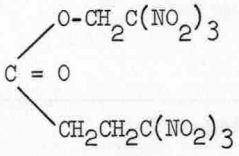
| 2 | 5 | 6 | 8 |
|---|---|---|---|
| 1352 | 1325 | 926 | 1098 |
| 1372 | | 976 | 1838 |

[79] See footnote 1, page 10.

**Composition:**

| | % |
|---|---|
| C | 18.6 |
| H | 1.6 |
| N | 21.8 |
| O | 58.0 |

C/H Ratio 0.202



**Molecular Weight:** $(C_6H_6N_6O_{14})$ 386

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -4.2 |
| CO % | 20.8 |

**Density:** gm/cc Form I 1.78

**Melting Point:** °C 93

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$ Form I (e)

| Crystal Axis | |
|---|---|
| α | 1.518 |
| β | 1.527 |
| γ | 1.546 |

**Impact Sensitivity, 2 Kg Wt:**

Bureau of Mines Apparatus, cm
Sample Wt 20 mg
Picatinny Arsenal Apparatus, in.
Sample Wt, mg
50% point, cm (a) 20

**Friction Pendulum Test:**

Steel Shoe
Fiber Shoe

**Vacuum Stability Test:**

cc/40 Hrs, at

| | | |
|---|---|---|
| 90°C | | ---- |
| 100°C | 48 hrs | 0.60 |
| 120°C | | |
| 135°C | | |
| 150°C | | |

**Rifle Bullet Impact Test:** Trials / %

Explosions
Partials
Burned
Unaffected

**200 Gram Bomb Sand Test:**

Sand, gm

**Explosion Temperature:** °C

Seconds, 0.1 (no cap used) ---
1 ---
5 50% point (Alhot bar) (a) 225
10
15
20

**Sensitivity to Initiation:**

Minimum Detonating Charge, gm
Mercury Fulminate
Lead Azide
Tetryl

**Ballistic Mortar, % TNT:** (b) 136

**Trauzl Test, % TNT:**

**75°C International Heat Test:**

% Loss in 48 Hrs

**Plate Dent Test:**

Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**100°C Heat Test:**

% Loss, 1st 48 Hrs
% Loss, 2nd 48 Hrs
Explosion in 100 Hrs

**Detonation Rate:**

Confinement
Condition
Charge Diameter, in.

| | | |
|---|---|---|
| Density, gm/cc | 1.60 | 1.76 |
| Rate, meters/second | 7760 | 8290 |

**Flammability Index:**

**Hygroscopicity:** % 30°C, 90% RH 0.00
75°C, 5 months Nil (a)

**Volatility:**

**Booster Sensitivity Test:**
- Condition
- Tetryl, gm
- Wax, in. for 50% Detonation
- Wax, gm
- Density, gm/cc

**Heat of:**
- Combustion, cal/gm: 1685
- Explosion, cal/gm
  - Gas Volume, cc/gm
- Formation, cal/gm: 307
- Fusion, cal/gm
- Sublimation, cal/gm (est): 804

**Specific Heat:** cal/gm/°C

**Burning Rate:**
- cm/sec

**Thermal Conductivity:**
- cal/sec/cm/°C

**Coefficient of Expansion:**
- Linear, %/°C
- Volume, %/°C

**Hardness, Mohs' Scale:**

**Young's Modulus:**
- E', dynes/cm²
- E, lb/inch²
- Density, gm/cc

**Compressive Strength:** lb/inch²

**Vapor Pressure:** (e)

| °C | mm Mercury |
|---|---|
| 65 | $3.3 \times 10^{-5}$ |
| 75 | $1.3 \times 10^{-4}$ |
| 85 | $4.2 \times 10^{-4}$ |
| 100 | $2.3 \times 10^{-3}$ |
| 120 | $1.4 \times 10^{-2}$ |

**Decomposition Equation:**
- Oxygen, atoms/sec (Z/sec): $4.4 \times 10^{21}$
- Heat, kilocalorie/mole (ΔH, kcal/mol): 43.4
- Temperature Range, °C
- Phase: Liquid

**Armor Plate Impact Test:**

**60 mm Mortar Projectile:**
- 50% Inert, Velocity, ft/sec
- Aluminum Fineness

**500-lb General Purpose Bombs:**

Plate Thickness, inches
- 1
- 1¼
- 1½
- 1¾

**Bomb Drop Test:**

**T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:**
- Max Safe Drop, ft

**500-lb General Purpose Bomb vs Concrete:**
- Height, ft
- Trials
- Unaffected
- Low Order
- High Order

**1000-lb General Purpose Bomb vs Concrete:**
- Height, ft
- Trials
- Unaffected
- Low Order
- High Order

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**Fragment Velocity:** ft/sec

At 9 ft

At 25½ ft

Density, gm/cc

**Blast (Relative to H-6):** Sphere Cylinder (h)

| **Air:** 1-lb Charge: | EW* | EV* | EW* | EV* |
|---|---|---|---|---|
| Peak Pressure | 0.91 | 0.84 | 0.81 | 0.75 |
| Impulse | 0.73 | 0.67 | 0.74 | 0.69 |
| Energy | | | | |

**Air, Confined:**

Impulse

**Under Water:**

Peak Pressure

Impulse

Energy

**Underground:**

Peak Pressure

Impulse

Energy

*EW, equivalent weight of H-6 for a unit weight of test mixture for equal performance at the same test distance; EV, equivalent volume of H-6 for a unit volume of test mixture for equal performance at the same test distance.

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Colorless

**Principal Uses:**

**Method of Loading:**

**Loading Density:** gm/cc Form I 1.783
Form II 1.677
Liquid, 99°C, 1.551

**Storage:**

Method Wet

Hazard Class (Quantity-Distance)

Compatibility Group

Exudation

Bruceton Safety Test Results: (g)

Mean and standard deviation of lengths of 0.300 diameter cylinder across which initiation is possible for 50% certainty:

| | |
|---|---|
| TNT | 0.391 ± 0.040 |
| RDX Comp B | 0.381 ± 0.042 |
| TNETB | 0.920 ± 0.059 |

Absolute Viscosity, poises: (e)

| | |
|---|---|
| Temp, 98.9°C | 0.173 |
| 106.5°C | 0.138 |

## 2,2,2-Trinitroethyl-4,4,4-Trinitrobutyrate (TNETB)

Solubility (Room Temperature): (a)

| Solvent | Solubility |
|---|---|
| Water | Insoluble |
| n-Hexane | Insoluble |
| Carbon tetrachloride | Insoluble |
| Ethanol | 5 gm/100 gm solvent |
| Chloroform | 5 gm/100 gm solvent |
| Benzene | 10 gm/100 gm solvent |
| Nitromethane | Very soluble |
| Glacial acetic acid | Very soluble |
| Ethyl acetate | Very soluble |

TNETB Forms Eutectics With the Following Compounds: (a)

| | |
|---|---|
| TNT | 57 |
| BTNES (bis(trinitroethyl) succinate) | 80+ |
| BTNEN (bis(trinitroethyl) nitramine) | 68.5 |
| TNB (trinitrobenzene) | 65 |
| Compound A ($C_4H_6N_4O_7$ formed by condensation of 1,1-dinitroethane) | 77 |
| Trinitroethyl trinitrobenzoate (27%) | 80.5 (f) |

Crystallographic Data: (a)

Three polymorphic crystalline forms have been observed. Low temperature Form I goes through a solid-solid transition at 89°C giving Form II. Form II has a melting point of 92.5° to 93°C. On cooling, Form II does not transform reversibly to Form I when 89°C is reached. However, Form II will transform to Form I at room temperature, usually taking a few hours to do so. Form III was observed, which appeared to be stable over a very narrow temperature range on the order of 0.2° to 0.3°C near 92.5°C.

Preparation: (d)

$(NO_2)_3CCH_2CH_2COCl$ + $(NO_2)_3CH_2OH$ —($H_2SO_4$)→ $(NO_2)_3CCH_2CH_2COOCH_2C(NO_2)_3$ + HCl

trinitrobutyryl chloride; trinitroethanol; sulfuric acid

2,2,2-trinitroethyl-4,4,4-trinitrobutyrate; hydrochloric acid

Laboratory experiments indicate that the present slow step involving overnight treatment of 4,4,4-trinitrobutyryl chloride with 2,2,2-trinitroethanol and aluminum chloride can be replaced by a fast and simple esterification in sulfuric acid. Using 100% sulfuric acid or fortified $H_2SO_4$, the ester can be prepared in yields of 95% to 98% in 24 hours at 25°C, in 5 hours at 50°C, or in 3 hours at 65°C. Above 65°C the reaction time is less, but the yield falls off and a less pure product is obtained. The crude white crystalline product on recrystallization from dilute methanol gives a material melting at 92° to 93°C.

Origin: (e)

TNETB belongs to a new class of explosives characterized by trinitromethyl groups, $-C(NO_2)_3$. The chemistry of this class of compounds was studied in Germany by Drs. Schenck and Schimmelschmidt, who discovered in 1942-1943 that trinitromethane or nitroform, $HC(NO_2)_3$, was the source of new explosive derivatives. Dr. Schenck prepared the stable solid alcohol, 2,2,2-trinitroethanol, from nitroform and formaldehyde. Dr. Schimmelschmidt reacted nitroform with unsaturated organic compounds, such as acrylic acid, and predicted in 1943 that the ester of 4,4,4-trinitrobutyric acid with trinitroethanol would be an interesting explosive.

In 1947 the U.S. Navy began a program to explore these compounds. The initial task of investigating the chemistry of trinitroethanol was undertaken by the Hercules Powder Company (Navy Contract NOrd-9925). The U.S. Rubber Company studied the chemistry of nitroform (Navy Contract NOrd-10,129). After preparation of the first laboratory samples of TNETB, considerable interest was aroused. In early 1950 the Naugatuck Chemical Division of U.S. Rubber Company was assigned to prepare 100 pounds of TNETB. The Bureau of Ordnance in July 1953 raised the production to 800 pounds with the assistance of the Hercules Powder Company in augmenting the production at Naugatuck (Navy Contract NOrd-11,280). TNETB is a high oxygen content explosive.

References: [80]

(a) J. M. Rosen, Properties of Trinitroethyl Trinitrobutyrate TNETB, NAVORD Report No. 1758, 17 December 1950.

(b) Bureau of Mines Report No. 3107, Part IX, Ballistic Mortar Tests on Trinitroethyl Trinitrobutyrate, 5 April 1950.

(c) L. D. Hampton and G. Svadeba, Evaluation of 2,2,2-Trinitroethyl-4,4,4-Trinitrobutyrate as a Constituent of Castable Explosives, NAVORD Report No. 2614, 30 September 1952.

(d) U.S. Rubber Company Quarterly Progress Report No. 23, Synthesis of New Propellants and Explosives, Navy Contracts NOrd-10-129 and -12,663, 19 August 1953.

(e) M. E. Hill, O. H. Johnson, J. M. Rosen, D. V. Sickman and F. Taylor, Jr., Preparation and Properties of TNETB, a New Castable High Explosive, NAVORD Report No. 3885, 27 January 1955.

(f) M. E. Hill, Synthesis of New High Explosives, NAVORD Report No. 2965, 1 April 1953.

(g) Jacob Savitt, A Sensitivity Test for Castable Liquid Explosives, Including Results for Some New Materials, NAVORD Report No. 2997, 22 October 1953.

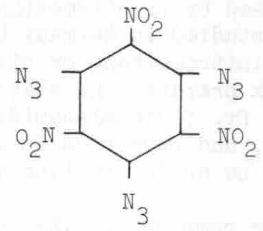
(h) R. W. Gipson, Sensitivity of Explosives, IX: Selected Physico-Chemical Data of Ten Pure High Explosives, NAVORD Report No. 6130, 18 June 1958.

[80] See footnote 1, page 10.

# Trinitro Triazidobenzene

**Composition:**

| | % |
|---|---|
| C | 21.4 |
| N | 50.0 |
| O | 28.6 |



C/H Ratio

**Molecular Weight:** ($C_6O_6N_{12}$) 336

**Oxygen Balance:**
$CO_2$ % -29
CO % 0.0

**Density:** gm/cc Crystal 1.81

**Melting Point:** °C Decomposes 131

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^D$
$n_{25}^D$
$n_{30}^D$

**Impact Sensitivity, 2 Kg Wt:**
Bureau of Mines Apparatus, cm (a) ≤ 25
Sample Wt 20 mg
Picatinny Arsenal Apparatus, in.
Sample Wt, mg

**Friction Pendulum Test:**
Steel Shoe
Fiber Shoe

**Vacuum Stability Test:**
cc/40 Hrs, at
90°C
100°C
120°C
135°C
150°C

**Rifle Bullet Impact Test:** Trials
%
Explosions
Partials
Burned
Unaffected

**200 Gram Bomb Sand Test:**
Sand, gm

**Explosion Temperature:** °C (a)

| Seconds, 0.1 (no cap used) | -- |
|---|---|
| 1 | -- |
| 5 | 150 |
| 10 | |
| 15 | |
| 20 | |

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm
Mercury Fulminate
Lead Azide
Tetryl

**Ballistic Mortar, % TNT:**

**Trauzl Test, %** PETN: 90

**75°C International Heat Test:**
% Loss in 48 Hrs

**Plate Dent Test:**
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**100°C Heat Test:**
% Loss, 1st 48 Hrs
% Loss, 2nd 48 Hrs
Explosion in 100 Hrs

**Detonation Rate:**
Confinement
Condition
Charge Diameter, in.
Density, gm/cc
Rate, meters/second

**Flammability Index:**

**Hygroscopicity:** % 30°C, 90% RH 0.00

**Volatility:**

Trinitro Triazidobenzene

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**
Density, gm/cc
Charge Wt, lb

**Total No. of Fragments:**
For TNT
For Subject HE

**Fragment Velocity:** ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

**Blast (Relative to TNT):**

**Air:**
Peak Pressure
Impulse
Energy

**Air, Confined:**
Impulse

**Under Water:**
Peak Pressure
Impulse
Energy

**Underground:**
Peak Pressure
Impulse
Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Greenish-yellow

**Principal Uses:** (c) Ingredient of primer mix

**Method of Loading:** Pressed
Dead presses at about 42,000 psi

**Loading Density:** gm/cc
At 42,000 psi 1.75

**Storage:**
Method
Hazard Class (Quantity-Distance)
Compatibility Group
Exudation None

Qualitative Solubilities at Room Temperature:

| Solvent | Solubility |
|---|---|
| Acetone | Readily soluble |
| Chloroform | Moderately soluble |
| Alcohol | Sparingly soluble |
| Water | Insoluble |

Compatibility with Metals:

Wet: Does not attack iron, steel, copper or brass.

Heat of:

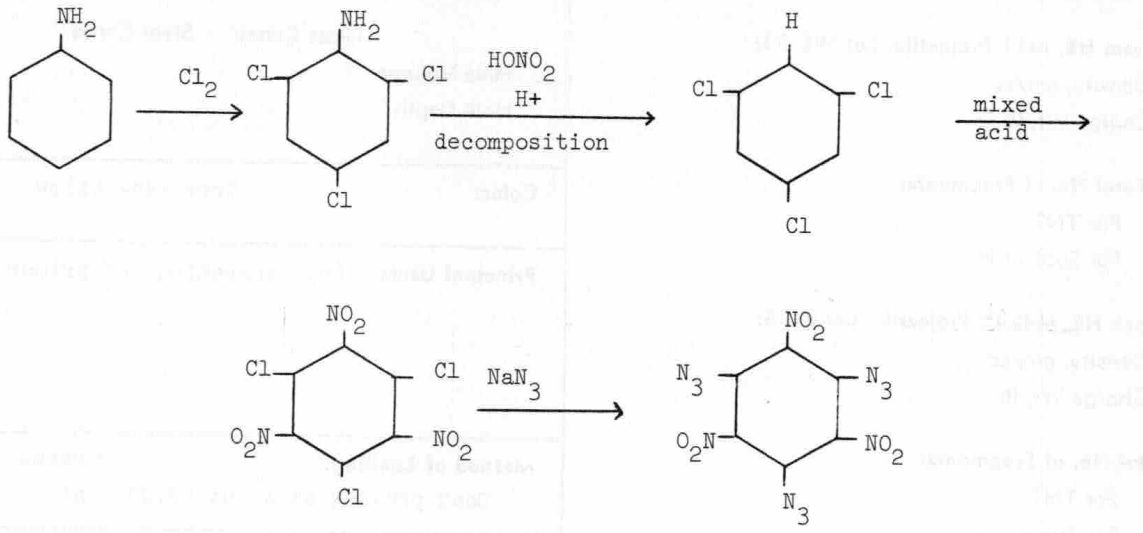
Combustion, cal/gm (a) 2554

Burning Rate: (b)

cm/sec 0.65

## Trinitro Triazidobenzene

Preparation: (e)




Aniline is chlorinated to form trichloroaniline. The amino group is eliminated by the diazo reaction. The resulting sym-trichlorobenzene is nitrated. This nitration is carried out by dissolving the material in warm 32% oleum, adding strong nitric acid, and heating to 140°-150°C until no trinitro trichlorobenzene (melting point 187°C) precipitates (Ref f). The chlorine groups are then replaced by azo groups. This is accomplished by adding an acetone solution of the trinitro trichlorobenzene, or better, and powdered substance alone, to an actively stirred solution of sodium azide in alcohol. The precipitated trinitro triazidobenzene is collected on a filter, washed with alcohol, water and dried. It may be purified by dissolving in chloroform, allowing the solution to cool, and collecting the greenish yellow crystals (melting point 131°C with decomposition).

Origin:

This initiating explosive was first prepared in 1923 by Turek who also perfected its manufacture.

References:[81]

(a) S. Helf, Tests of Explosive Compounds Submitted by Arthur D. Little, Inc., PATR 1750, 24 October 1949.

(b) A. F. Belyaeva and A. E. Belyaeva CR a.s. USSR 52, 503-505 (1946) Chemical Abstracts 41, 4310.

A. E. Belyaeva and A. F. Belyaeva, Doklady Akad Nauk. USSR 56, 491-494 (1947).

(c) French Patent 893,941, 14 November 1944 (Chemical Abstracts 47, 8374).

(d) A. D. Yoffe, "Thermal Decomposition and Explosion of Azides," Proc. Roy Soc A208, 188-199 (1951).

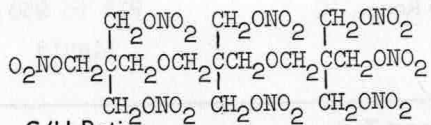
(e) T. L. Davis, The Chemistry of Powder and Explosives, John Wiley and Sons, Inc., New York (1943), p. 436.

(f) O. Turek, Chim et Ind 26, 781 (1931); German Patent 498,050; British Patent 298,981.

[81] See footnote 1, page 10.

**Composition:**

| | % |
|---|---|
| C | 24.6 |
| H | 3.3 |
| N | 15.3 |
| O | 56.8 |



C/H Ratio 0.175

**Molecular Weight:** $(C_{15}H_{24}N_8O_{26})$ 732

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -35 |
| CO % | -2.2 |

**Density:** gm/cc Crystal 1.58

**Melting Point:** °C 82 to 84

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^D$ $n_{25}^D$ $n_{30}^D$

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 9 |
| Sample Wt, mg | 24 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | Unaffected |

**Vacuum Stability Test:**

cc/40 Hrs, at

| | | |
|---|---|---|
| 90°C | | ---- |
| 100°C | Pure | 2.45 |
| 120°C | Specially purified | 1.94 |
| 135°C | | |
| 150°C | | |

**Rifle Bullet Impact Test:**

| | Trials | % |
|---|---|---|
| Explosions | | |
| Partials | | |
| Burned | | |
| Unaffected | | |

**200 Gram Bomb Sand Test:**

Sand, gm 58.9

**Explosion Temperature:** °C

| Seconds, 0.1 (no cap used) | --- |
|---|---|
| 1 | --- |
| 5 | 225 |
| 10 | |
| 15 | |
| 20 | |

**Sensitivity to Initiation:**

Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | ---- |
| Lead Azide | 0.30 |
| Tetryl | ---- |

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**75°C International Heat Test:**

% Loss in 48 Hrs

**Plate Dent Test:**

| |
|---|
| Method |
| Condition |
| Confined |
| Density, gm/cc |
| Brisance, % TNT |

**100°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 1.15 |
| % Loss, 2nd 48 Hrs | 0.75 |
| Explosion in 100 Hrs | None |

**Detonation Rate:**

| | |
|---|---|
| Confinement | None |
| Condition | Pressed |
| Charge Diameter, in. | 0.5 |
| Density, gm/cc | 1.56 |
| Rate, meters/second | 7650 |

**Flammability Index:**

**Hygroscopicity:** %

**Volatility:**

Tripentaerythritol Octanitrate (TPEON)

**Booster Sensitivity Test:**
- Condition
- Tetryl, gm
- Wax, in. for 50% Detonation
- Wax, gm
- Density, gm/cc

**Heat of:**

| | |
|---|---|
| Combustion, cal/gm | 2632 |
| Explosion, cal/gm | 1085 |
| Gas Volume, cc/gm | 762 |
| Formation, cal/gm | |
| Fusion, cal/gm | |

**Specific Heat:** cal/gm/°C

Specific Impulse:

| | |
|---|---|
| lb-sec/lb (calculated) | 240 |

**Burning Rate:**
cm/sec

**Thermal Conductivity:**
cal/sec/cm/°C

**Coefficient of Expansion:**
- Linear, %/°C
- Volume, %/°C

**Hardness, Mohs' Scale:**

**Young's Modulus:**
- E', dynes/cm²
- E, lb/inch²
- Density, gm/cc

**Compressive Strength:** lb/inch²

**Vapor Pressure:**
°C mm Mercury

**Decomposition Equation:**

| | |
|---|---|
| Oxygen, atoms/sec (Z/sec) | |
| Heat, kilocalorie/mole (ΔH, kcal/mol) | 23.1 |
| Temperature Range, °C | 215 to 250 |
| Phase | Liquid |

**Armor Plate Impact Test:**

**60 mm Mortar Projectile:**
- 50% Inert, Velocity, ft/sec
- Aluminum Fineness

**500-lb General Purpose Bombs:**

Plate Thickness, inches
- 1
- 1¼
- 1½
- 1¾

**Bomb Drop Test:**

**T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:**

Max Safe Drop, ft

**500-lb General Purpose Bomb vs Concrete:**
- Height, ft
- Trials
- Unaffected
- Low Order
- High Order

**1000-lb General Purpose Bomb vs Concrete:**
- Height, ft
- Trials
- Unaffected
- Low Order
- High Order

# Tripentaerythritol Octanitrate (TPEON)

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**Fragment Velocity:** ft/sec

At 9 ft

At 25½ ft

Density, gm/cc

**Blast (Relative to TNT):**

**Air:**

Peak Pressure

Impulse

Energy

**Air, Confined:**

Impulse

**Under Water:**

Peak Pressure

Impulse

Energy

**Underground:**

Peak Pressure

Impulse

Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** White

**Principal Uses:** High explosive and as possible plasticizer for nitrocellulose

**Method of Loading:** Cast or pressed

**Loading Density:** gm/cc

Pressed at 60,000 psi: 1.565

**Storage:**

Method: Dry

Hazard Class (Quantity-Distance)

Compatibility Group

Exudation: None

Hygroscopicity, Gain or Loss in Wt, %:

| Time, Hrs | % RH at 30°C | | |
|---|---|---|---|
| | 40 | 70 | 90 |
| 24 | -0.008 | +0.01 | +0.04 |
| 48 | -0.02 | -0.01 | +0.02 |
| 144 | -0.04 | -0.03 | -0.02 |
| 192 | -0.04 | -0.02 | ----- |
| 216 | -0.004 | -0.01 | +0.03 |

Solubility:

| Solvent | Solubility |
|---|---|
| Water | Insoluble |
| Alcohol | Soluble |
| Chloroform | Soluble |
| Acetone, hot | Very soluble |
| Benzene, hot | Very soluble |

## Tripentaerythritol Octanitrate (TPEON)

### Compatibility With Other High Explosives:

#### 100°C Vacuum Stability Test:

| | NTN | PETN | RDX | TPEON |
|---|---|---|---|---|
| ml gas/40 hrs, 5 gm sample | 0.14 | 2.15 | 0.39 | 2.45 |
| ml gas/40 hrs, 5 gm sample of 50/50, TPEON/HE | 1.89 | 1.71 | 2.32 | — |

### Dipentaerythritol Hexanitrate (DPEHN)-TPEON Fusions:

| % TPEON | % DPEHN | Solidification Time, Days | MP, °C |
|---|---|---|---|
| 100 | 0 | — | 83 |
| 95 | 5 | 3 | 68 |
| 90 | 10 | 3 | 69 |
| 80 | 20 | 5 | 73 |
| 50 | 50 | 30 | 60 (Eutectic) |
| 20 | 80 | 5 | 63 |
| 10 | 90 | 3 | 69 |
| 0 | 100 | — | 73 |

### Preparation:

(a)

Twenty grams (0.054 mol) of nitration grade tripentaerythritol (TPE) (99%) minimum purity) were slowly added, with stirring, to 160 gm (2.55 mol) of 99% nitric acid at a temperature of -25° to 0°C. On equivalent weight basis, this quantity of 99% nitric acid corresponds to an excess of 6.3 times the TPE used. After addition of the TPE, the reaction mixture was stirred for about one hour at 0° to 5°C and poured into eight times its volume of cracked ice. The product, when allowed to stand overnight, was crushed under water; filtered with suction; and washed copiously with water. It was then treated twice with about 5 times its weight of a 1% ammonium carbonate solution, stirred for several hours, filtered and washed with water until the final washings were neutral to litmus. The final product was washed successively with 50 cc each of ethanol and ether. The material dried in air weighed 37.8 gm or 96% of theory based on TPE. It had a melting range of 71° to 74°C. Crystallization of the crude TPEON from chloroform was found to be the most suitable method of obtaining pure TPEON.

### Origin:

TPEON prepared by the reaction of tripentaerythritol and 99% nitric acid at 0° to 10°C was reported by Wyler in 1945 (J. A. Wyler to Trojan Powder Company: U.S. Patent 2,389, 228, 20 November 1945).

References:[82]

(a) J. J. LaMonte, H. J. Jackson, S. Livingston, L. B. Silberman and M. M. Jones, The Preparation and Explosive Properties of Tripentaerythritol Octanitrate, PATR No. 2490, 1958.

(b) K. Namba, J. Yamashita and S. Tanaka, "Pentaerythritol Tetranitrate," J Ind Explosives Soc (Japan) 15, 282-9 (1954); CA 49, 11283 (1955).

(c) S. D. Brewer and H. Henkin, The Stability of PETN and Pentolite, OSRD Report No. 1414.

(d) E. Berlow, R. H. Barth and J. E. Snow, The Pentaerythritols, ACS Monograph No. 136, Reinhold Publishing Corporation, New York, 1958.

[82] See footnote 1, page 10.

# Tritonal, 80/20

**Composition:**
%

| | |
|---|---|
| TNT | 80 |
| Aluminum | 20 |
| C/H Ratio | |

**Impact Sensitivity, 2 Kg Wt:**

| | |
|---|---|
| Bureau of Mines Apparatus, cm | 85 |
| Sample Wt 20 mg | |
| Picatinny Arsenal Apparatus, in. | 13 |
| Sample Wt, mg | 16 |

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | Unaffected |

**Rifle Bullet Impact Test:** Trials

| | % |
|---|---|
| Explosions | 60 |
| Partials | 0 |
| Burned | 0 |
| Unaffected | 40 |

**Explosion Temperature:** °C

| | |
|---|---|
| Seconds, 0.1 (no cap used) | 610 |
| 1 | 520 |
| 5 Decomposes | 470 |
| 10 | 465 |
| 15 | |
| 20 | |

**75°C International Heat Test:**
% Loss in 48 Hrs

**100°C Heat Test:**
% Loss, 1st 48 Hrs
% Loss, 2nd 48 Hrs
Explosion in 100 Hrs

**Flammability Index:** 100

**Hygroscopicity:** % 30°C, 90% RH 0.00

**Volatility:**

**Molecular Weight:** 81

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -77 |
| CO % | -38 |

**Density:** gm/cc Cast 1.72

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n^D_{20}$
$n^D_{25}$
$n^D_{30}$

**Vacuum Stability Test:**
cc/40 Hrs, at

| | |
|---|---|
| 90°C | |
| 100°C | 0.1 |
| 120°C | 0.2 |
| 135°C | -- |
| 150°C | 0.8 |

**200 Gram Bomb Sand Test:**
Sand, gm

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | |
| Lead Azide | 0.20 |
| Tetryl | 0.10 |

**Ballistic Mortar, % TNT:** (a) 124

**Trauzl Test, % TNT:** (b) 125

**Plate Dent Test:** (c)

| | |
|---|---|
| Method | B |
| Condition | Cast |
| Confined | No |
| Density, gm/cc | 1.75 |
| Brisance, % TNT | 93 |

**Detonation Rate:**

| | | |
|---|---|---|
| Confinement | None | None |
| Condition | Cast | Pressed |
| Charge Diameter, in. | 1.0 | 1.0 |
| Density, gm/cc | 1.71 | 1.72 |
| Rate, meters/second | 6475 | 6700 |

# Tritonal, 80/20

**Booster Sensitivity Test:** (d)

| | |
|---|---|
| Condition | Cast |
| Tetryl, gm | 100 |
| Wax, in. for 50% Detonation | 0.58 |
| Wax, gm | |
| Density, gm/cc | 1.75 |

**Heat of:** (c)

| | |
|---|---|
| Combustion, cal/gm | 4480 |
| Explosion, cal/gm | 1770 |
| Gas Volume, cc/gm | |
| Formation, cal/gm | |
| Fusion, cal/gm | |

**Specific Heat:** cal/gm/°C (b)

| | |
|---|---|
| At -5°C | 0.23 |
| Density, gm/cc | 1.74 |
| At 20°C | 0.31 |

**Burning Rate:**
cm/sec

**Thermal Conductivity:**
cal/sec/cm/°C (b) $11 \times 10^{-4}$
Density, gm/cc 1.73

**Coefficient of Expansion:**
Linear, %/°C

Volume, %/°C

**Hardness, Mohs' Scale:**

**Young's Modulus:** (b)

| | |
|---|---|
| E', dynes/cm² | $6.67 \times 10^{10}$ |
| E, lb/inch² | $0.97 \times 10^{6}$ |
| Density, gm/cc | 1.72 |

**Compressive Strength:** lb/inch² (b) 2340
Density, gm/cc 1.75

**Vapor Pressure:**
°C mm Mercury

**Decomposition Equation:**
Oxygen, atoms/sec (Z/sec)
Heat, kilocalorie/mole (ΔH, kcal/mol)
Temperature Range, °C
Phase

**Armor Plate Impact Test:** (e)

**60 mm Mortar Projectile:**

| | | |
|---|---|---|
| 50% Inert, Velocity, ft/sec | 509 | >1100 |
| Aluminum Fineness | 100 | 12 |

**500-lb General Purpose Bombs:**

| Plate Thickness, inches | Trials | % Inert |
|---|---|---|
| 1 | 0 | |
| 1¼ | 6 | 100 |
| 1½ | 6 | 33 |
| 1¾ | 0 | |

**Bomb Drop Test:** (e)

**T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:**

Max Safe Drop, ft

**500-lb General Purpose Bomb vs Concrete:**

| | Seal 4,000 | Seal 5,000 |
|---|---|---|
| Height, ft | | |
| Trials | 34 | 14 |
| Unaffected | 32 | 14 |
| Low Order | 0 | 0 |
| High Order | 2 | 0 |

**1000-lb General Purpose Bomb vs Concrete:**

| | Seal 5,000 |
|---|---|
| Height, ft | |
| Trials | 24 |
| Unaffected | 23 |
| Low Order | 0 |
| High Order | 1 |

# Tritonal, 80/20

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

| | |
|---|---|
| Density, gm/cc | 1.71 |
| Charge Wt, lb | 2.272 |

**Total No. of Fragments:**

| | |
|---|---|
| For TNT | 703 |
| For Subject HE | 616 |

**3 inch HE, M42A1 Projectile, Lot KC-5:**

| | |
|---|---|
| Density, gm/cc | 1.73 |
| Charge Wt, lb | 0.914 |

**Total No. of Fragments:**

| | |
|---|---|
| For TNT | 514 |
| For Subject HE | 485 |

**Fragment Velocity:** ft/sec

| | |
|---|---|
| At 9 ft | 2460 |
| At 25½ ft | 2380 |
| Density, gm/cc | 1.72 |

**Blast (Relative to TNT):** (f)

**Air:**

| | |
|---|---|
| Peak Pressure | 110 |
| Impulse | 115 |
| Energy | 119 |

**Air, Confined:**

| | |
|---|---|
| Impulse | 130 |

**Under Water:**

| | |
|---|---|
| Peak Pressure | 105 |
| Impulse | 118 |
| Energy | 119 |

**Underground:**

| | |
|---|---|
| Peak Pressure | 117 |
| Impulse | 127 |
| Energy | 136 |

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Gray

**Principal Uses:** GP bombs

**Method of Loading:** Cast

**Loading Density:** gm/cc 1.65-1.72

**Storage:**

| | |
|---|---|
| Method | Dry |
| Hazard Class (Quantity-Distance) | Class 9 |
| Compatibility Group | Group I |
| Exudation | |

Preparation:

Tritonal is prepared by adding TNT and aluminum separately to a steam-jacketed melt kettle equipped with a stirrer. Heating of the kettle and mixing of the ingredients are continued until all the TNT is melted. When the viscosity of the mixture is considered satisfactory (about 85°C), the tritonal is poured into projectiles or bombs the same as TNT.

## Tritonal, 80/20

Origin:

The Addition of aluminum to increase the power of explosives was proposed by Escales in 1899 and patented by Roth in 1900 (German Patent 172,327). Some recent studies, directed towards establishment of the optimum amount of aluminum in the TNT/Aluminum system, have shown that (1) the blast effect increases to a maximum when the aluminum content is 30% (Ref g); the brisance, as measured by the Sand Test, passes through a maximum at about 17% aluminum (Ref h); in Fragmentation Tests, no maximum is observed, additions of aluminum causing a decrease in efficiency over the entire range from 0% to 70% aluminum (Ref i); and (4) the rate of detonation of cast charges is continuously decreased by additions of aluminum up to 40% (Ref j). For all practical purposes it is concluded that the addition of 18% to 20% aluminum to TNT improves its performance to a maximum. This conclusion is in agreement with that of British workers who measured performance of aluminized TNT-mixtures based on extensive Lead Block Test data (Ref k).

Tritonal, consisting of 80% TNT and 20% aluminum, was developed and standardized in the United States during World War II for use in bombs.

References:[83]

(a) L. C. Smith and E. H. Eyster, Physical Testing of Explosives, Part III, Miscellaneous Sensitivity Tests, Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.

(c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(d) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

(e) Committee of Div 2 and 8, NDRC, Report on HBX and Tritonal, OSRD No. 5406, 31 July 1945.

(f) W. R. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Tech Div Lecture, 9 April 1948.

(g) W. B. Kennedy, R. F. Arentzen and C. W. Tait, Survey of the Performance of TNT/Al on the Basis of Air-Blast Pressure and Impulse, OSRD Report No. 4649, Division 2, Monthly Report No. AES-6, 25 January 1945.

(h) W. R. Tomlinson, Jr., Develop New High Explosive Filler for AP Shot, PATR No. 1290, First Progress Report, 19 May 1943.

(i) W. R. Tomlinson, Jr., Develop New High Explosive Filler for AP Shot, PATR No. 1380, Second Progress Report, 12 January 1944.

(j) L. S. Wise, Effect of Aluminum on the Rate of Detonation of TNT, PATR No. 1550, 26 July 1945.

(k) Armament Research Dept, The Effect of Aluminum on the Power of Explosives, British Report AC-6437, May 1944 (Explosives Report 577/44).

[83] See footnote 1, page 10.

Tritonal, 80/20

(1) Also see the following Picatinny Arsenal Technical Reports on Tritonal:

| 0 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|
| 1530 | 1693 | 1444 | 1635 | 1956 | 1737 | 2138 |
| 1560 | 2353 | | | | 2127 | |
| 2010 | | | | | | |

**Composition:**

| | % |
|---|---|
| HMX | 70.0 |
| Nitrocellulose (13.15% N) | 15.0 |
| Nitroglycerin | 10.7 |
| 2-Nitrodiphenylamine | 1.3 |
| Triacetin | 3.0 |

C/H Ratio

**Impact Sensitivity, 2 Kg Wt:**
Bureau of Mines Apparatus, cm
Sample Wt 20 mg
Picatinny Arsenal Apparatus, in.
Sample Wt, mg

**Friction Pendulum Test:**

| | |
|---|---|
| Steel Shoe | Unaffected |
| Fiber Shoe | Unaffected |

**Rifle Bullet Impact Test:** Trials

| | % |
|---|---|
| Explosions | |
| Partials | |
| Burned | |
| Unaffected | |

**Explosion Temperature:** °C
Seconds, 0.1 (no cap used)
1
5
10
15
20

**75°C International Heat Test:**
% Loss in 48 Hrs

**90°C Heat Test:**

| | |
|---|---|
| % Loss, 1st 48 Hrs | 0.28 |
| % Loss, 2nd 48 Hrs | 1.12 |
| Explosion in 100 Hrs | None |

**Flammability Index:**

**Hygroscopicity:** %

**Volatility:**

**Molecular Weight:** 281

**Oxygen Balance:**

| | |
|---|---|
| $CO_2$ % | -26 |
| CO % | -0.5 |

**Density:** gm/cc Pressed 1.72

**Melting Point:** °C

**Freezing Point:** °C

**Boiling Point:** °C

**Refractive Index,** $n_{20}^{D}$
$n_{25}^{D}$
$n_{30}^{D}$

**Vacuum Stability Test:**
cc/40 Hrs, at

| | |
|---|---|
| 90°C | ---- |
| 100°C | 1.29 |
| 120°C 29 hours | 11+ |
| 135°C | |
| 150°C | |

**200 Gram Bomb Sand Test:**

| | |
|---|---|
| Sand, gm | 66.4 |

**Sensitivity to Initiation:**
Minimum Detonating Charge, gm

| | |
|---|---|
| Mercury Fulminate | ---- |
| Lead Azide | 0.30 |
| Tetryl | ---- |

**Ballistic Mortar, % TNT:**

**Trauzl Test, % TNT:**

**Plate Dent Test:**
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

**Detonation Rate:**
Confinement
Condition
Charge Diameter, in.
Density, gm/cc
Rate, meters/second (calculated) 8500

*See footnote on following page.

Veltex No. 448*

**Booster Sensitivity Test:**
Condition
Tetryl, gm
Wax, in. for 50% Detonation
Wax, gm
Density, gm/cc

**Heat of:**
Combustion, cal/gm 2359
Explosion, cal/gm 1226
Gas Volume, cc/gm
Formation, cal/gm
Fusion, cal/gm

Compression at Rupture: % 8.26

Work to Produce Rupture:
ft-lb/inch$^3$ 9.62

**Burning Rate:**
cm/sec

**Thermal Conductivity:**
cal/sec/cm/°C

**Coefficient of Expansion:**
Linear, %/°C
Volume, %/°C

**Hardness, Mohs' Scale:**

**Young's Modulus:**
E', dynes/cm$^2$ $0.24 \times 10^{10}$
E, lb/inch$^2$ $0.35 \times 10^{5}$
Density, gm/cc

**Compressive Strength:** lb/inch$^2$ 2720

**Vapor Pressure:**
°C mm Mercury

*Name assigned by Dr. Mark M. Jones, formerly of PA; based on original development by James H. Veltman.

**Decomposition Equation:**
Oxygen, atoms/sec (Z/sec)
Heat, kilocalorie/mole (ΔH, kcal/mol)
Temperature Range, °C
Phase

**Armor Plate Impact Test:**

**60 mm Mortar Projectile:**
50% Inert, Velocity, ft/sec
Aluminum Fineness

**500-lb General Purpose Bombs:**

Plate Thickness, inches
1
1¼
1½
1¾

**Bomb Drop Test:**

**T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:**

Max Safe Drop, ft

**500-lb General Purpose Bomb vs Concrete:**

Height, ft
Trials
Unaffected
Low Order
High Order

**1000-lb General Purpose Bomb vs Concrete:**

Height, ft
Trials
Unaffected
Low Order
High Order

**Fragmentation Test:**

**90 mm HE, M71 Projectile, Lot WC-91:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**3 inch HE, M42A1 Projectile, Lot KC-5:**

Density, gm/cc

Charge Wt, lb

**Total No. of Fragments:**

For TNT

For Subject HE

**Fragment Velocity:** ft/sec

At 9 ft

At 25½ ft

Density, gm/cc

**Blast (Relative to TNT):**

**Air:**

Peak Pressure

Impulse

Energy

**Air, Confined:**

Impulse

**Under Water:**

Peak Pressure

Impulse

Energy

**Underground:**

Peak Pressure

Impulse

Energy

**Shaped Charge Effectiveness, TNT = 100:**

| | Glass Cones | Steel Cones |
|---|---|---|
| Hole Volume | | |
| Hole Depth | | |

**Color:** Orange

**Principal Uses:** High mechanical strength machinable explosive

**Method of Loading:** Pressed

**Loading Density:** gm/cc

At 6,700 psi 1.72

**Storage:**

Method Dry

Hazard Class (Quantity-Distance)

Compatibility Group

Exudation None

Machinability Excellent

## Veltex No. 448

Preparation:

The preparation of this class of explosive compositions is illustrated by the method used for Veltex No. 448: Place 675 cc of water in a slurry kettle equipped with an agitator. Add 5.85 gm of 2-nitrodiphenylamine and agitate for several minutes to obtain dispersion. Then add 93.7 gm of water-wet nitrocellulose (dry weight 67.5 gm) in small portions. Raise the temperature to 48°C and maintain this temperature, but continue the agitation. A mixture of 48.2 gm of nitroglycerin and 13.5 gm of triacetin is added over a 5-minute period, with the mixing continuing for an additional 10 minutes at 48°C. The HMX (350 gm) is added over a 5-minute period with agitation continued for 30 minutes at 48°C. The slurry is cooled to room temperature and filtered. The filter cake is dried to a moisture content between 8% and 12%. The incorporation of this mix is completed by rolling 50 gm portions at a temperature of approximately 90°C. The finished colloid is then preheated on a heat table at 66°C. Increments of 25 gm each are pressed at 6700 psi for four minutes at 71°C. A cylinder is then built up by pressing together four 25 gm increments for a dwell time of 15 minutes.

Origin:

Veltex is the name given to a series of closely related nitrocellulose compositions prepared in 1957 at Picatinny Arsenal by the solventless process used for propellants. These compositions all contain a high percentage of solid high explosive. They were investigated to determinate the suitability of the Holtex type explosive developed by Hispano Suiza of Switzerland, France and Spain, but for which the composition was not reported (Ref a). Compositions similar to Veltex No. 448 and containing 60% to 80% HMX, with either nitroglycerin or triethyleneglycol dinitrate as colloiding agent for nitrocellulose, have also been prepared. In general these compositions showed lower heat stability than that of conventional high explosive compositions.

Reference:[84]

(a) U.S. Air Intelligence Information Report IR-269-55, Holtex--Hispano Suiza Explosive, 4 May 1955.

[84]See footnote 1, page 10.

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| 176(C) | Solid Propellants, Part Two (U) |
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| 178(C) | +Properties of Explosives of Military Interest, Section 2 (U) (REPLACED BY -177) |
| 179 | Explosive Trains |
| 180 | *Principles of Explosive Behavior |
| 185 | Military Pyrotechnics, Part One, Theory and Application |
| 186 | Military Pyrotechnics, Part Two, Safety, Procedures and Glossary |
| 187 | Military Pyrotechnics, Part Three, Properties of Materials Used in Pyrotechnic Compositions |
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